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TECHNICAL REPORT
FD-13

METHODS FOR CONTROLLING FRAGMENTATION OF DRIED FOODS DURING COMPRESSION

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N. I. Ishler

TRONCHEMICS RESEARCH, INCORPORATED
South Hackensack, New Jersey

Contract No. DA 19-129-AMC-2 (X) (OI 9001)

August 1965

U. S. Army Materiel Command
U. S. ARMY NATICK LABORATORIES
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FOREWORD

Foods preserved by modern dehydration procedures rehydrate rapidly to yield products which are generally indistinguishable from their undehydrated counterparts in odor, taste, texture and appearance. The 60 to 90 percent reduction in weight incident to dehydration represents a collateral advantage of increasing significance. In theory, dehydration should permit a reduction in volume approximating the water removed. Reducing the volume of dehydrated food provides obvious advantages in terms of transport, storage, and ratio of food to packaging material, especially when the reduced bulk is concentrated as a rectangular module favorable to packaging and packing. These values are amplified in terms of the soldier who must carry on his person whatever food he may consume during prolonged periods in a hostile area.

This investigation is based on recognition of the importance of compression techniques for reducing the volume of dehydrated foods, and on the common observation that compression of dehydrated foods may result in major structural changes similar to grinding. Such changes adversely affect the acceptability of many familiar food items through alterations of appearance, texture and possibly other physical properties. The primary objective of this investigation is the development and demonstration of feasible methods for minimizing the fragmentation attending the compression of dehydrated foods.

The investigation covered by this report was performed at the Food Research Laboratory of Tronchemics Research Inc., 480 U. S. Route 46, South Hackensack, New Jersey. Mr. Norman H. Ishler was the Official Investigator. His collaborators were Mr. A. J. Knipper, Mr. S. Lederman, Dr. K. Al-Delaimy, Dr. R. La Rocca, Mr. W. G. Timpe, Dr. A. R. Touba, and Mr. J. R. Boss.

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ABSTRACT

Methods have been developed whereby a broad range of dehydrated foods can be compressed at 1000 psi into dense, cohesive bars which rehydrate readily with little fragmentation to original characteristics. Examination included 15 food types. Measurement of fragmentation is described. Storage stability is reported. A progress flow diagram is included.

SUMMARY

Methods are described for preparing food bars from freeze dried chicken, raw beef, ground cooked beef, peas, shrimp, corn, chili con carne, beef stew, rice, onions, scrambled eggs, peaches and spinach. These bars, having been compressed at 1000 psi. into discs approximately ½" thick and 1½" in diameter are cohesive enough to withstand normal handling and have a good appearance. The bars can be rehydrated by normal means to yield food pieces of the shape and size of the uncompressed food with little fragmentation or even distortion of the original appearance. Compression of the foods listed above without the treatments described in this report yields bars of little cohesion which, when rehydrated, yield broken food pieces and in many cases only a finely dispersed slurry.

Effective treatments for reducing fragmentation include spraying water, glycerin or propylene glycol on the dried food prior to compression. Redrying water sprayed bars by vacuum oven to a moisture level of less than 2% does not affect the high quality associated with freeze dried foods (i.e., fresh flavor and rapid rehydration). Effective treatment for scrambled eggs comprise substituting partial cooking for the usual complete cooking before freeze drying. No anti-fragmentation additives were used.

Also described in this report is a test based on objective measurements which provides a valid quantitative index to fragmentation or decreased particle size resulting from the compression of freeze-dried foods. The results from this test are reproducible, clearly showing the degree of fragmentation with a single number. This number (I_f) approaches unity as the fragmentation is reduced. In some cases, the I_f has been reduced from as high as 13 for untreated foods to as low as 1.2 by treating the food prior to compression operation. The mathematical treatment and mathematical meaning of the I_f number is given.

Storage stability studies were carried out on all of the food bars at $70^{\circ}F$, $100^{\circ}F$ and cycling between $0^{\circ}F$ and $40^{\circ}F$.

In some cases an alternate treatment is reported for food bars where storage stability studies indicated poor performance for bars treated a specific way.

Techniques are described r improving rehydration rate and cohesion of the food bars. These techniques include the use of additives such as starch, gum arabic and calcium pectinate. Also, methods are described for controlling surface moisture of the food particles prior to compression to achieve optimum rehydration and cohesion characteristics. Without this control, rehydration time of some food studied would be greater than 3 hours, whereas all of the bars described in this report rehydrate in less than 30 minutes and in many cases in less than 7 minutes.

The use of oil as a means of preventing off-flavor in compressed onion is described.

The exclusion of light from glycerin treated pea bars was found to prevent the whitening effect encountered by other workers.

Equilibration followed by compression at elevated temperature is reported as a means of reducing fragmentation. Also, methods are given for reducing equilibration time from one hour to a few minutes in some instances.

Experiments have indicated that stopping the freeze drying cycle of peas when the food had reached a moisture of 7.5%, with subsequent compression and a continuation of drying in a vacuum oven to a moisture of less than 2% yielded a cohesive bar that showed little or no fragmentation upon rehydration.

INTRODUCTION AND GENERAL PRINCIPLES

Improvements in the technology of dehydrating foods have solved many of the problems of providing high-quality food rations to members of the Armed Forces. Dehydration in many cases provides effective preservation of the food product, and at the same time markedly reduces the weight required to be shipped and ultimately to be carried in the pack by the individual. However, notably in the case of freeze dried foods where virtually no shrinkage occurs in dehydration, the volume of the dehydrated food remains close to that of the original starting material.

Hence, the need has been recognized to increase the caloric density of dehydrated foods. This may be accomplished in some cases by filling the existing void spaces in dehydrated foods. Another approach is to compress the dehydrated product so that a given weight of material will occupy a smaller volume than would otherwise be the case.

However, many dehydrated foods undergo severe fragmentation, particularly when they are compressed at pressures above 1000 psi. It is an ultimate objective of this project to find means of treating certain specified dehydrated foods so as to substantially reduce the amount of fragmentation which would otherwise occur upon compression in the range of 1000 to 2000 psi. It is also an objective of this project to develop a relatively simple, reproducible method for measuring the fragmentation which occurs so that the effectiveness of the treatments devised can be evaluated and controlled.

I. INDEX OF FRAGMENTATION

In order to evaluate treatments and processes that are developed to reduce the fragmentation of dehydrated foods, it was necessary first to devise a means of measuring this fragmentation. Therefore, this objective is covered first.

The first basic consideration was to select a test method that would reflect various degrees of fragmentation. The test should be based on objective measurements and must be relatively simple to perform and reproduce.

A second consideration was to express the results of such a test in a single number or index which would equal unity if no fragmentation occurs and would increase in value as the degree of fragmentation increases.

It was also considered desirable, although not essential, that the Index of Fragmentation developed should be reasonably comparable when applied to various types of food materials. That is, it would seem desirable if an Index of Fragmentation of 5 could be taken to indicate approximately the same degree of breakage which had occurred during compression of shrimp as a similar number would indicate for a markedly different product (e.g., rice). It should be recognized that this degree of comparability may never be attained in full because of the differences in type of breakage which are likely to occur in materials which are structurally as different as shrimp and rice, for example.

Screen analysis is probably the most obvious way of measuring the particles size and hence the degree of fragmentation. The preliminary experiments indicated that a wet screen analysis was preferred over a dry screen analysis. The method developed in the current work is based on rehydrating the compressed foods and making a wet screen analysis of the particles using a water spray to transport the particles from one screen to another. The values obtained from this analysis are mathematically reduced to a single number which meets the following specifications:

1) It is a ratio in terms of fragmentation after compression to fragmentation before compression.

2) It approaches unity as breakage due to compression is minimized.

3) It becomes larger as breakage produces smaller and smaller particles.

4) It permits a rough comparison of the amount of fragmentation which has occurred in large food pieces (e.g., shrimp) and small pieces (e.g. peas) even though different sieve sizes are involved.

This method of determining Index of Fragmentation has proved to have good reproducibility and to be indicative of the amount of fragmentation of food as judged by appearance and organoleptic means. This test has been successfully applied to all of the foods studied.

The primary objective of this project has been successfully met by developing treatments for freeze dried foods which enable them to be compressed into bars which will, upon rehydration, return to their original shape with little breakage occurring and with essentially the same flavor and appearance as the uncompressed freeze dried foods. The volume of the freeze dried foods is reduced by the compression step to less than one quarter of the original volume and in some cases to one ninth of the original volume.

The preliminary work on this project indicated that the most successful approach to reducing fragmentation is to soften the freeze dried foods prior to compression. If the food is soft enough, it will yield to compression, forming a bar without breaking. This approach has been successfully applied to most of the foods specified under the contract.

A. Food Softening

To soften the foods prior to compression, several "plasticizers" were evaluated. It was found that water, propylene glycol, glycerin and alcohol softened the foods sufficiently to allow compression with little fragmentation. To achieve optimum results from these "plasticizers" and to obtain bars with good physical properties, specific techniques were worked out for each food using the basic principle of softening the food.

1. Water Treatment

Freeze dried foods with moisture levels from 5-20% will compress into bars with little fragmentation occurring. The higher the level of water, the lower the degree of fragmentation. After compression, the food can be dried to below 2% moisture in a vacuum oven without any apparent change in the quality associated with freeze dried foods (i.e., rapid rehydration and fresh flavor). However, if too high a moisture level is used (this level varies with each food) the food is adversely affected by the second drying operation, the food taking on the characteristics of the conventional dried foods (i.e., slower rehydration and lack of fresh flavor).

Three techniques have been used to obtain freeze dried foods with moisture levels from 5-20%: 1) Spraying the dried foods with a fine mist until the desired increase in weight is obtained; 2) Stopping the freeze dried operation when the food has reached the desired moisture level and 3) Allowing freeze dried food to equilibrate in a humidity chamber until the food absorbs the desired amount of water. Of the three methods, spraying the water appears to be most satisfactory with relation to control and time required. Stopping the freeze drying operation at a desired moisture level was very difficult and several attempts were necessary before even one success was achieved. Introducing the desired moisture in a humidity chamber usually requires several hours as compared with less than an hour required for the spray method. The spray method was therefore used as the method of choice in most cases.

The amount of moisture added before compression also affects the cohesiveness of the bar and its rate of rehydration. Foods compressed at moistures below optimum level have poor cohesion but rehydrate rapidly while foods compressed above optimum moisture have very good cohesion but rehydrate very slowly.

In all cases, it appears important to control the moisture on the surface of the food pieces. Higher surface moisture levels tend to produce more cohesive bars, but lower rehydration rates. Even a sample with a low moisture level may be too cohesive if the compression is carried out before the water (sprayed on) has penetrated the surface. Therefore, it is desirable to compress after the foods have equilibrated to insure a fairly uniform moisture level throughout. This equilibration may vary, depending on the food, from a few minutes to an hour. Generally, a food that rehydrates slowly will need a longer equilibration time before compression and re-drying than a food which rehydrates rapidly. After determining the optimum moisture level and equilibration time to reduce the fragmentation of a specific food, a greater cohesion or rehydration rate may still be desired. Surface moisture may be reduced by a warm dry air current or increased by a light spray immediately before compressing.

In some cases, it is possible to add certain additives to the water being sprayed on the food to obtain either greater rehydration rate or cohesion without adversely affecting the other. Gum arabic has been successfully used in rice to increase cohesion without affecting rehydration rates. Modified low viscosity starches have been used to increase rehydration rates of bars.

2. Propylene Glycol and Glycerin Treatment

Propylene glycol and glycerin can be used effectively in ranges from 5-15% to reduce fragmentation due to compression. The higher level is limited by taste factors. Propylene glycol is more effective in reducing fragmentation than glycerin; however, the maximum level of propylene glycol that can be used because of the bitter taste is less than that of glycerin which mainly contributes sweetness to the product. The use of these plasticizers requires compression at elevated temperatures. Little or no plasticizing occurs at room temperatures. The optimum temperature of compression for the foods worked on under this contract is 60°C. The main advantage of using propylene glycol and glycerin to soften the food tissue is that it does not require a second drying operation as is needed after water treatment. However, these plasticizers generally affect storage stability adversely at high temperatures (100°F).

The level of propylene glycol and glycerin used is not critical, and has little or no effect on rehydration. Usually the cohesion of the bar is improved by the use of these plasticizers.

Spraying propylene glycol or glycerin was the most effective method of distributing these additives uniformly. It was found helpful to equilibrate the samples at 60°C after spraying prior to compression.

An equilibration and heating time of one hour was used. Shorter equilibration times are possible especially when heating only thin layers at a time (i.e., the use of radiant heating plates on single layers of peas reduced the time to 5 minutes).

3. Alcohol Treatment

Ethyl alcohol will soften the food particles to allow compression without excessive fragmentation. However, for greatest effectiveness, the treated food should be compressed at elevated temperatures (60^{0}C). Significant losses have been experienced due to evaporation under these conditions.

Alcohol treatment offers little advantage over the water treatment except for the ease of removal after compression.

MATERIALS AND METHODS

I. MATERIALS

The food products selected for experimental work in this project were chosen in conformity with the requirements of the Statement of Work as set forth in the request for proposal on which this project is based. Readily available commercial products were chosen wherever possible to achieve a degree of standarization which would not be possible if the individual food material were prepared in the contractor's laboratory under small scale research conditions. When not available commercially, the products were purchased in their raw or natural states, and dehydrated using a RePP Freeze Dryer (see section under equipment) according to military specifications for these foods. As experimental work progressed, it was found neccessary in some cases to treat the food in its raw or natural state in some manner prior to freeze drying in order to accomplish the desired reduction of fragmentation.

Data concerning those foods which were purchased in the dehydrated state meeting specifications of the Statement of Work are tabulated in Table I. Products that required special attention are described below.

A FREEZE DRIED STRAWBERRIES

Fresh strawberries were purchased from a local fruit store and dehydrated in a RePP Freeze Dryer. The final moisture was less than 3%. It was found necessary to treat with calcium chloride and low methoxy pectin prior to freeze drying in pursuit of a treatment for the reduction of fragmentation. These pre-drying treatments are discussed under Results and Discussion,

TABLE I
DATA ON COMMERCIALLY-PURCHASED DEHYDRATED FOODS

Component	Suppliers	Size	Moisture Actual	Moisture Specification
Shrimp	United Fruit Corp.	26/29 lb.	1.61	2-5
Beef (cooked & ground)	Wilson & Co.	1/4" cubes	----	2-3
Chickens	Wilson & Co.	3/8" diced	2.64	2. 5-3
*Rice	General Foods	Whole Grain	3.02	3-5
Onions	Basic Veg. Prod. Inc.	Chopped	3.0	3-5
Peaches	Seeman Bros. Inc.	Halves	12.0	10-15
Peas	United Fruit Corp.	--------	1.4	1-2
Corn	United Fruit Corp.	--------	1.4	1-2

*Actual moisture as purchased was 8-12%; was dried in air oven to 3%.

B. FREEZE DRIED SPINACH

Frozen spinach was purchased from a local vegetable store and prepared for freeze drying according to Military Specification LP/P.DES C-208-63. The final moisture was below 2% which was within specifications for freeze-dried materials.

C. FREEZE-DRIED MUSHROOMS

Freeze-dried mushrooms were obtained from United Fruit & Food Corp. Since it was found necessary to treat the mushrooms before freeze drying, the fresh product was purchased from a local store, pretreated, and prepared for freeze drying according to Military Specifications LP/P.DES C-190-62. The product was then freeze dried in a RePP Freeze Dryer.

D. FREEZE-DRIED COTTAGE CHEESE

Fresh cottage cheese was purchased from the local food store. The product was frozen directly in the freeze dryer by evaporative freezing to obtain dehydrated product of distinguishable curds. This procedure was followed because when cottage cheese was frozen in a conventional freezer and then freeze-dried, the cheese became matted which was undesirable for use according to Military Specification LP/P.DES C-197-62

E. FREEZE DRIED SCRAMBLED EGGS

Freeze dried scrambled eggs were prepared in the laboratory at various cooking times as described under Results and Discussions. The basic procedure, however, followed the appropriate military specification.

F. FREEZE DRIED, DICED, RAW BEEF

Raw beef (round cut) was purchased from a local butcher and prepared for freeze drying according to Military Specification LP/P DES C-204-63. The raw meat was diced approximately 1/2" in thickness and 1" in the other two dimensions. This cutting operation caused considerable leaking of tissue fluid on the surface of meat which subsequently caused rehydration problems.

G. DEHYDRATED BEEF STEW

For the purpose of this report, beef stew was prepared according to Military Specification LP/T DES C-187-62. The formula is shown in Table II.

TABLE II
FORMULA FOR DEHYDRATED BEEF STEW

COMPONENT (Dehydrated)	PERCENT	SUPPLIER
Cooked beef pieces	51.8	Prepared in lab.
Potatoes	15.5	" " "
Peas	6.0	" " "
Carrots	6.0	" " "
Onions, sliced	3.4	Basic Vegetable Products, I[illegible]
Gravy mix		Prepared in lab.
Soup and Gravy Base, Beef	8.9	Thomas J. Lipton, Inc.
Waxy maize starch	6.9	National Starch
Hydrolyzed Vegetable Proteins	0.9	The Nestle Co., Inc.(HVP type [illegible]
Onion powder	0.4	Basic Vegetable Products, Inc.
White pepper	0.1	McCormack & Co., Inc.
Caramel Coloring	0.1	T. Mitchell Co.
TOTAL	100.0	

Raw beef, diced potatoes and carrots, and peas were purchased locally, cooked and freeze dried by Tronchemics Research Inc. The Soup and Gravy base, Beef was made up according to military specification MIL-S-3271C

H. DEHYDRATED CHILI CON CARNE

Chili Con Carne was prepared according to military specification LP/P DES C-186-62. The formula is given in Table III. The soup and gravy base used was the same as that described under Beef Stew.

TABLE III
FORMULA FOR CHILI CON CARNE

COMPONENT		
iite pea beans	59	Prepared in the lab
recooked ground beef (ehydrated)	25	Wilson & Co.
asoning mix		Prepared in the lab
mato powder	6.6	Patterson Canning Co.
oup & Gravy Base, Beef	4.0	Thomas J. Lipton, Inc.
ili powder seasoning	3.0	Griffith's Laboratories, Inc.
lt	2.4	Obtained locally
rlic Powder	?	Sun Speed Vegetable, Inc.
TOTAL	100.0	

e beans were purchased locally, cooked and freeze-dried in a RePP Freeze yer. All other components were obtained in the dehydrated state, requiring o further processing except for blending.

ll ingredients used to reduce fragmentation conform to current requirements f the F.D.A. Furthermore, no process or treatment was used which is known to dversely affect the wholesomeness, the vitamin content, or the biological uality of the protein of the compressed product.

[illegible]. EQUIPMENT

Major pieces of equipment required for the successful performance of this contract are tabulated in Table IV .

TABLE IV

MAJOR PIECES OF EQUIPMENT

Freeze Dryer	RePP Industries Inc. Gardener, N. Y.	FFD-40
Hydraulic Press	Fred S. Carver Inc. Summit, N. J.	150
Vacuum Oven	National Appliance Co. Portland,Oregon	
High Vacuum Pump	Arthur S. LaPine & Co.	S-2
Environmental Chamber	Enviratron Company Burbank, California	
Moisture Meter	Ohaus State Corp. Union, N.J.	6000

III. METHODS

A. FREEZE-DRYING

Freeze-drying of foods at Tronchemics Research, Inc. was carried out in a RePP Sublimator (FFD-42) modified to utilize adjustable electrically heated radiant plates.

B. COMPRESSION PROCEDURE

A Carver hydraulic press with 6" square plates and a cylinder 3" high with a movable piston was used to compress the dried foods into bars. The weights of the dried foods were adjusted so that after compression the bars would be approximately 1/2" thick with parallel top and bottom surfaces of approximately 2 square inches each. Where an experiment called for compressing the sample at 60°C., electrically heated plates were used in the press and the cylinder was preheated at 60°C for one hour. Unless indicated otherwise for a specific experiment, all samples were compressed at 1100 psi pressure, this being 100 psi over the minimum of 1000 psi called for in the contract specifications. The time required to reach maximum pressure applied and the time remaining at the pressure was five seconds unless indicated otherwise.

C. SPRAYING

Many of the food materials were sprayed with water, propylene, glycol or glycerine prior to compression to reduce breakage of the food particles during the compression operation and to increase cohesion. Spraying was done with a paint spray type nozzle (pressures 25-50 psig), from a container having a capacity of one quart.

D. EQUILIBRATION

After spraying dried foods with water, proplyene glycol or glycerin, it was necessary to provide equilibration for the treatment agent to penetrate the food. Equilibration time in a sealed container after spraying varied depending on the nature of the product. Equilibration times were as low as 5 minutes for peas and as high as two hours for Chili Con Carne. Equilibration is performed at 20°C for water treated samples and at 60°C for glycerin and propylene glycol treated samples.

E. REDRYING

It was necessary to remove water from bars so treated in order to prevent possible spoilage of the foods due to excessive moisture content. After water treated foods were compressed the resulting bars were redried in a vacuum oven at temperatures ranging from 40-60°C for at least 5 hours to reduce the moisture content to less than 2%. Since the quantities of water involved were low, no adverse effects due to moistening and redrying were observed.

F. EVALUATION TESTS

1. INDEX OF FRAGMENTATION (I_f)

The development of a method for determining the degree of fragmentation was one of the major objectives of this project. The experimental work leading to this development, along with the method ultimately adopted is discussed below under Results and Discussion, Section I, Index of Fragmentation.

2. pH

The pH of the compressed food bars has been determined by using a Beckman pH Meter Model G. A ten gram aliquot of the dry bar was dispersed in 100 ml. distilled water.

3. DROP TEST

In this method, a 3/4" steel ball weighing 28.2 gm. is dropped from a height of 10" on to the center of the bar. An assembly with an electromagnet has been made to allow the ball to be dropped from a predetermined height. The bar is placed on a cast iron plate (i.e., botton of ring stand). The number of drops necessary to crack or break the bar is recorded.

4. % MOISTURE

The moisture of the untreated samples is determined by an Ohaus Moisture Balance with the heat adjusted for each food to prevent scorching. Validity of results was checked using a vacuum oven method (A.O.A.C. where applicable).

In the treated samples, part of the additive (glycerol or propylene glycol was lost in the drying step. Time vs. weight loss was plotted and extrapolated to zero time from the straight line portion of the curve (constant rate of weight loss) in order to determine weight loss due to moisture.

5. DENSITY

The bar is weighed and measured at least 10 minutes after compression and density is computed as grams/cc. The control (not compressed) is measured by determining the weight of product necessary to fill a 500 ml. graduate.

6. REHYDRATION TIME

Samples were tasted periodically during rehydration to determine the time required to fully rehydrate the food. The food was judged to be fully rehydrated when the texture was uniformly soft throughout. At this time, the sample was also cut in half and inspected visually to determine whether the water had completely penetrated the interior. The temperature and amount of water used were determined.

7. ORGANOLEPTIC EVALUATION

Organoleptic evaluations of flavor, aroma, texture and color were performed by a trained panel of not less than three people.

8. STORAGE STABILITY

Samples were vacuum packed or nitrogen packed in poly-foil-poly flexible pouches. All samples were placed in storage under the conditions specified by the contract (70°F, 100°F, and cycling between 0°F and 40°F). In addition, samples were placed in 0°F storage, to serve as additional controls. Initial and six months storage evaluations were conducted for most products studied.

9. HUMIDITY-MOISTURE EQUILIBRIUM

The wink (weight equilibrium) method of determining the humidity moisture equilibria of the food bars and uncompressed foods was used. The saturated salt solutions used and corresponding humidities at 73°F are as follows:

SALT	% R.H.
Potassium acetate	22.9
Magnesium chloride	32.9
Chromium trioxide	39.2
Sodium dichromate	54.1
Sodium bromide	58.5
Sodium nitrite	64.8
Sodium chloride	75.5
Ammonium sulfate	80.1
Potassium chromate	86.5
Ammonium monophosphate	92.9

RESULTS AND DISCUSSION

SECTION I - INDEX OF FRAGMENTATION

I. SELECTION OF EXPERIMENTAL PROCEDURE

Screen analysis was considered to be the most direct approach to measuring fragmentation of compressed foods. Wet screen analysis was selected in preference to dry screen analysis because of several inherent disadvantages of the latter. Some of these disadvantages are listed as follows:

1. There is no practical way to break up a cohesive dry bar to permit dry screening without producing further fragmentation.

2. Separation of the bar components by rehydration would require redrying before dry screen analysis could be performed. This would be time consuming and shrinkage of food pieces would probably occur, exaggerating the indications of fragmentation.

3. Some fragile products would be further fragmented by abrasion on the screen during dry screen analysis.

The wet screen analysis has several advantages that make it particularly suitable for the analysis of compressed food bars. They may be listed as follows:

a. The rehydration step gently breaks apart the compressed bar without causing further fragmentation.

b. Further fragmentation is not likely in the screening operation because most products are less fragile after rehydration.

c. The analysis can be made immediately without waiting an additional time for redrying the sample.

d. The analysis requires a relatively short time.

e. Screens are the only special equipment needed.

f. Preliminary experiments indicated that a wet screen analysis distinguishes various degrees of fragmentation and is fairly reproducible.

In view of the above considerations, the wet screen procedure was selected as most promising for further investigation.

II. STANDARDIZATION OF THE WET SCREEN ANALYSIS

A. SELECTION OF SCREEN SIZES

An attempt was made to develop a rationale for the selection of screens for the individual food products which would serve as a guide not only for selecting screens to be used for specific foods to be studied in this project, but also for any subsequent foods which might be considered for compression in future work either on this project or by the U. S. Army Natick Laboratories in its continuing effort. This rationale was developed to fulfill the following considerations:

1. The top screen should be selected so that it will retain the greater part of the raw material being investigated. That is, if compression and resulting fragmentation has not occurred, most of the rehydrated food will be retained by the top screen selected.

2. The top screen should be large enough so that, if any significant fragmentation occurs, the breakage will be reflected by an increased amount of material passing through the screen. For example, if a screen with a 5 mm opening were selected as the top screen for a fragmentation of freeze dried shrimp, it is apparent that considerable breakage of the shrimp could occur with very little effect upon the resulting screen analysis data.

3. A sufficient number of screens should be used in the analysis to adequately cover the range of particle sizes important to the accomplishment of the objectives of this project.

4. The measurement of extremely fine particle size distributions was considered unimportant for the purposes of this project. This conclusion is based on the assumption that once the food material has been reduced to 1/16th or less of its original size, its desirable texture, apparent characteristics, and eating qualities are no longer acceptable and precise measurement of particle size distribution is unimportant.

5. On the basis of these and other considerations, the selection of screens was made as follows:

(a) Five screens will be used for each analysis.

(b) The bottom sieve will be a U. S. Standard Sieve #100 or #200 and will remain constant, being analogous to the "pan" in dry screening.

(c) The top sieve will be selected so that it is ½ the size of the smallest screen opening that will allow 90% or more of the uncompressed product to pass through.

(d) The remaining three sieves will each be ½ of the screen opening size of the next larger sieve immediately above it.

(e) If a specific product has a dimension that is 1½" or greater, the above rules will not apply, but instead the following five screens will be used:

Sieve No.	Screen Opening
5/8	16 mm
5/16	8 mm
5	4 mm
10	2 mm
100	149 mm

Within the scope of this project, it was felt that item (e) immediately above was necessary to cover very large pieces of dehydrated foods. Particles broken up to sizes larger than 5/8" would still retain the basic textural characteristics. If information about the + 5/8" fraction is desired, pieces of that size could readily be counted and measured if necessary.

In commercial flaked onions, a few pieces were found to be exceptionally long and not representative of the average size of the particles. Therefore, a screen selected to allow 100% of the onions to pass through would have to be relatively very large. Because of this, item (c) above states that the top sieve will be ½ the size of the smallest screen that allows 90% or more of the product to pass through. In the case of onions, the #5/16, (8 mm opening) screen allowed 97% of the product to pass through so, by definition, a #5 screen (4 mm opening) was the top screen used.

B. SCREENING TECHNIQUES

In the wet screen analysis some method is necessary to transport the fines from the top screen to lower screens (smaller openings). Two methods were evaluated, 1) spraying water on top of the screens, and 2) dipping the screens in and out of water, It was found that dipping the screens was not as efficient as spraying the screens because considerable time was required to transport all of the fines to the lower screens (at least 30 minutes) by the immersion method. Only a few minutes were required on even the more difficult product when direct spraying was used.

The spraying method was adopted and subsequent work was directed toward standardization of the spray conditions. Initial experiment indicated that a spray of too high a velocity would break up the particles and a spray of too low a velocity would not carry all of the fines to the lower screens within a practical time limit. A total flow rate of 2500 ml/min was found to be suitable for all of the products evaluated to date. The time of spraying each screen was found to differ for each product depending on the following factors:

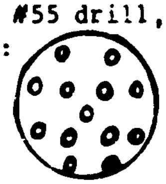
1. Size of particle.
2. Cohesion between particles.
3. Fragility of particle.

In chicken it was found that one minute on each screen was adequate whereas 3 minutes were necessary on the top screen in analyzing onions. Time of spraying was determined by spraying the top of each screen until little or no additional material passed through to the next screen. Care was also taken to ensure that excessive spraying did not in itself cause fragmentation of the rehydrated food materials. Time and temperature of rehydration prior to the screen analysis varied according to the product. If the raw material as purchased included special rehydration instructions, these were followed. If specific instructions did not accompany the raw material, boiling water was added to the compressed bar and allowed to stand until rehydration was apparently complete. Regardless of the method chosen, rehydration was carried to an extent in which the drained weight was at maximum value.

After screen analysis, the fraction on each screen is washed onto filter paper and weighed wet. A Buchner funnel, using vacuum, was preferred for speed over the gravity flow of a standard funnel. The total weight of the fraction varied little when running duplicate experiments using the Buchner funnel whereas the standard funnel resulted in relatively large variations probably due to retention of excess water on the filter paper. Also the Buchner funnel method resulted in a considerably lower drained weight which indicated more efficient draining. In order to standardize the use of the Buchner funnel, a time of fifteen seconds was adopted for drawing air through the funnel after the water is gone and air is first heard to pass through the filter paper.

WET SCREEN ANALYSIS - STANDARD METHOD

Material - a. U. S. Standard Sieves from W. S. Tyler Company.
b. Perforated plate type spray nozzle, $\frac{1}{2}$" diameter, having 13 holes made by a #55 drill, arranged as indicated by the diagram:



c. Buchner funnel, porcelain, fixed perforated plate, diameter 111 mm.
d. Filter paper - Whatman #4, 11 cm.
e. Brass aspirator (filter pump).

Method - Rehydrate sample in beaker, transfer contents to stack of five sieves in series and spray at 2500 ml/min. The screen size and time of water spray is given in table below under heading of SCREEN ANALYSIS - CONDITIONS. Remove top sieve and continue spraying for the specified time on the second sieve. Repeat for the other three sieves. Wash each fraction quantitatively from its sieve into a beaker.

The fractions collected in the beakers are weighed by pouring into a Buchner funnel onto filter paper, washing into funnel any pieces that adhere to side of beaker with additional water. The funnel is then filled with additional water to distribute the particles and vacuum is applied. After the water is gone and air is drawn through the paper for 15 seconds, the filter paper with contents is weighed wet allowing a tare for filter paper as determined experimentally. Index of Fragmentation is calculated as shown below.

SCREEN ANALYSIS - CONDITIONS

Product	Wt.(g)/Bar	Top Screen Sieve #	Top Screen Spray Time (min)	2nd Screen Sieve #	2nd Screen Spray Time	3rd Screen Sieve #	3rd Screen Spray Time	4th Screen Sieve #	4th Screen Spray Time	Bottom Screen Sieve#	Bottom Screen Spray Time
Peaches	20	5/8"	1	5/16"	5 sec.	5	5 sec.	10	5 sec.	100	0
Onions	15	5	3	10	2 min.	18	1 min.	35	1 min.	100	0
Rice	15	5	1	10	2 min.	18	1 min.	35	1 min.	100	0
Chicken	10	5/16"	1	5	1 min.	10	1 min.	18	1 min.	100	0
Shrimp	10	5/8"	1	5/16"	30 sec.	5	30 sec.	10	30 sec.	100	0
Peas	10	5/16"	1	5	1 min.	10	1 min.	18	1 min.	200	0
Corn	10	5/16"	1	5	2 min.	10	1 min.	18	1 min.	200	0
Ground Beef	12	5/16"	1	5	1 min.	10	1 min.	18	1 min.	200	0
Raw Beef	10	5/8"	3	5/16"	1 min.	5	1 min.	10	1 min.	200	0
Mushrooms	10	5/16"	1	5	1 min.	10	1 min.	18	1 min.	200	0
Spinach	10	5/16"	1	5	1 min.	10	1 min.	18	1 min.	100	0

SCREEN ANALYSIS - CONDITIONS (CONT'D)

Product	Wt.(g)/ Bar	Top Screen Sieve #	Top Screen Spray Time (min)	2nd Screen Sieve #	2nd Screen Spray Time	3rd Screen Sieve #	3rd Screen Spray Time	4th Screen Sieve #	4th Screen Spray Time	Bottom Screen Sieve #	Bottom Screen Spray Time
Beef Stew	10	5/16"	1	5	1 min.	10	1 min.	18	1 min.	200	0
Chili Con Carne	12	5/16"	1	5	1 min.	10	1 min.	18	1 min.	200	0
Strawberries	10	5/8"	1	5/16"	1 min.	5	1 min.	10	1 min.	200	0
Cottage Cheese	13	5	2	10	1 min.	18	1 min.	35	1 min.	200	0
Scrambled Eggs	10	5/16"	*	5	*	10	*	18	*	200	*

* Dipping method was used instead of spraying. Details given below under XIV, SCRAMBLED EGGS.

IV. MATHEMATICAL TREATMENT OF RESULTS

The mathematical treatment of the screen analysis data to obtain an "Index of Fragmentation" should fulfill two objectives.

(1) It should result in a physically meaningful index.

(2) It should be simple.

The simplest method would be to calculate by simple interpolation, or to pick from a graphic representation of a particle size distribution, a representative particle size which divides the total sample into some arbitrarily fixed weight percentages of oversize and undersize and express the Index of Fragmentation as the ratio of the control particle size dividied by the size of the sample under examination.

The most common method for graphic representation of a particle size distribution is to plot the cumulative weight percent undersize or oversize on either a normal or a logarithmic scale versus a scale based on the probability integral. (Normal-probability and log-probability grid). Less frequently used are such distribution functions as the Rosin-Rammler and the square root probability functions.[(1)] No attempt was made to determine the applicability of these functions to all the experimental distributions. However, upon investigating several of the experimental particle size distributions, it became apparent that a strict expression of each one of the distributions by any one function, i.e., a straight line plot on appropriate graph paper, was improbable, thus making the value of the "graphical" method questionable. In addition, this method would not make allowance for the possibility that a particle size derived in this manner may represent any number of more or less uniform size distributions which happen to be split into these arbitrary weight fractions. A physically more meaningful expression should place due emphasis on the particle characteristic of importance. If a sample is examined, visually and organoleptically, which has undergone fragmentation, it becomes obvious that the smaller particles contribute to the objectionableness out of proportion to their weight fraction shown in the screen analysis. What is observed visually is the sum of the cross sectional areas of the particles. Thus the number extracted mathematically from each screen analysis should have a relation to the cross sectional area of a given weight of particles.

[(1)] Tate, R. W. and W. R. Marshall. Chem. Eng. Progress, 49:161, 226 (1953).

we assume, for reasons of simplicity, that we are dealing with spherical rticles, we can calculate the actual number, n, of particles in each reen fraction:

$$n = \frac{w}{\frac{\pi}{6} d_m^3 \times \rho \times 10^{-3}} \qquad (1)$$

where w = weight of screen fraction in grams.

d_m = mean particle diameter of screen fraction in millimeters derived from screen openings; i.e., for particles less than 8 mm, but greater than 4 mm, d_m = 6 mm.

ρ = density of material in grams per milliliter.

The cross sectional area, as, of a sphere is:

$$a_s = d_m^2 \times \frac{\pi}{4} \qquad (2)$$

The total cross sectional area a_f of an entire screen fraction is obtained by multiplying a_s by the number of particles, n, in that fraction:

$$na_s = nd_m^2 \times \frac{\pi}{4} = a_f \qquad (3)$$

Substituting from equation (1) for n in equation (3), we obtain: (4)

$$a_f = \frac{w}{\frac{\pi}{6} d_m^3 \times \rho \times 10^{-3}} \times d_m^2 \times \frac{\pi}{4}$$

$$= \frac{w}{d_m} \times \frac{1}{\rho} \times \frac{6}{4 \times 10^{-3}}$$

Equation (4) may be further simplified by eliminating the numerical constants $\frac{1}{\rho}$ .. $\frac{6}{4 \times 10^{-3}}$ to:

$$a_f = f\left(\frac{w}{d_m}\right) \qquad (5)$$

The sum of a_f of all screen fractions, divided by the sum of the weights of all screen fractions, yields a number which is a function of the cross sectional area of 1 gram of sample, the area number, A:

$$A = f\,(a_f) = f_1 \left(\frac{\sum \frac{w}{d_m}}{\sum w} \right) \qquad (6)$$

If A_c is the area number obtained for the untreated, uncompressed control sample, and A_e the area number of a compressed sample, the fraction $\frac{A_e}{A_c}$ is called the Fragmentation Index, I_f, of the compressed sample. For comparison purposes, it may be noted that the area number A obtained for each particle size distribution is closely related to the reciprocal of the mean volume-surface diameter,

$$d_{vs} = \frac{nd^3}{nd^2}$$

For a complete listing and discussion of the several statistical mean particle diameters and mean diameters of distinct physical meaning, reference is made to Dallavalle.[2]

It is apparent from the derivation of this index that it will assume the same value whether one product is broken down from 10 to 5 mm or another from 2 to 1 mm. Thus a comparison of the compression effect on different products of different original size (i.e., chicken vs. rice) is possible.

One limitation is placed on the ultimate mathematical correctness of this index by the experimental method of the wet screen analysis. The 100 mesh (0.149 mm) screen is used in lieu of a pan, but the mean diameter of the smallest size fraction (the fraction retained on the 100 mesh "pan") is calculated as one half of the next larger screen opening, instead of the actual mean, i.e.:

$$\frac{1.0}{2} = 0.5 \text{ instead of:}$$

$$\frac{1.0 + 0.15}{2} = 0.425.$$

This, of course, weights the smallest fraction somewhat more than it should be by definition.

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(2) Dallavalle, J. M. Micromeritics, Chapter 3. N.Y., Pitman Publishing Corp.

Any traces of product going through the 100 mesh screen normally are disregarded. However, when any amount of product goes through the 100 mesh sieve (e.g., untreated chicken meat loses 5%) disregarding this amount does not yield an index strictly comparable to one obtained on another product, and an improved method may have to be developed for this type of product. To date, no significant problem has been encountered.

The following table, Table V, illustrates the method of calculation used in the reported work to obtain the Index of Fragmentation described here. Table V also represents the general form of work sheet from which I_f is normally computed.

In addition, the area number A for each sample can also be obtained by using the weight % in each fraction instead of the weight in gms, where column 8 becomes weight % = 100, column 9 becomes:

$$\Sigma \frac{\text{weight \%}}{d_m}$$

$$\text{and } A = \frac{\Sigma \frac{\text{weight \%}}{d_m}}{100}$$

However, the weight % itself is a desired result; this method of calculation is not used since it involves more calculations than the direct method using the weight in grams.

INDEX OF FRAGMENTATION - SAMPLE CALCULATION - WORK SHEET

1	2	3	4	5	6	7	8	9	10	11
Sample							$\sum w$	$\sum \frac{w}{d_m}$	A	$\bar{I}_f$
	Mesh Size range, mm d_m	5 -8+4 6	10 -4+2 3	18 -2+1 1.5	35 -1+0.5 0.75	100 -0.5+0.15 0.25			$\frac{\text{Column 9}}{\text{Column 8}}$	$\frac{A_{exp.}}{A_{control}}$
Onions	w, gms.	38.0	29.1	0.3	---	---	67.4	---	---	---
Untreated, Uncompressed (Control)	w/d_m	6.3	9.7	0.2	---	---	---	16.2	0.24	1
Onions	w/gms.	2.5	31.8	11.5	2.5	0.5	48.8	---	---	---
Untreated, Compressed	w/d_m	0.4	10.6	7.7	3.3	2.0	---	24.0	0.49	2.1
Onions	w, gms.	13.2	26.8	2.9	0.6	0.1	43.6	---	---	---
10% Glycerin allowed to stand 20 hours at room temperature before compression	w/d_m	2.2	8.9	1.9	0.8	0.4	---	14.2	0.33	1.4

RESULTS AND DISCUSSION

SECTION II - REDUCTION OF FRAGMENTATION

I. PEAS

A. REDUCTION OF FRAGMENTATION

The compression of freeze-dried peas results in a complete breakdown of the appearance and structure with a fine powder being the principal product. The high Index of Fragmentation (18) for untreated compressed peas indicates the severity of this fragmentation. Two methods of nearly eliminating this fragmentation have been developed; water treatment and glycerin treatment.

1. Water Treatment

This method involves the partial rehydration of the freeze dried food to soften the tissue, compressing the food into bars and removing the water by drying. This method is preferred to glycerin treatment because of superior storage stability at higher temperatures (100°F) (discussed below). The major disadvantage of water treatment is the redrying operation not required for the glycerin treatment.

A low Index of Fragmentation ($I_f = 1.2$) was achieved with water treatment (Table VI). In this method freeze dried loose peas of the usual size (e. g. 3/8 " in diameter) were used. The bulk density of the mass was 0.16 and the apparent density of the individual peas was 0.28 grams/cc.

The dried peas were sprayed with a fine mist of sufficient water to raise their moisture content to 6.4%. After two minutes on a tray open to the atmosphere, 10 grams of the sprayed peas were compressed to a thickness of about ½" with a pressure of 1100 psi. The compressed bar was dried in a vacuum oven under a pressure of about 1½" Hg absolute at an oven temperature of 45°C for 6 hours to reduce the moisture content to 1.5%. The resulting dried bar had the same appearance and occupied the same volume as the compressed bar before drying and had a density of 0.71 g/cc. It was composed of dried peas, of flattened or rough pyramidal shape, which retained the light green color of the original dried peas. The compressed bar could be separated easily into the individual peas with the fingernails. The bar withstood 5 drops in the "falling ball test". On full rehydration with boiling water the bar separated into its individual peas without agitation and the peas recovered from the flattened state to substantially their original size and shape, all within 6 minutes. The flavor and texture of the product were substantially the same as that obtained by fully rehydrating, in the same way, the original freeze dried peas without any intermediate steps of partial rehydration, compression and drying. Virtually no visible fines were observed. On organoleptic evaluation of this rehydrated product, there was no powdery feel in the mouth. The peas regained the original full green color of undried fresh peas.

When it was attempted to compress the freeze dried peas, without the moisture treatment, the peas broke up into powder losing entirely their initial shape and form. On rehydration, a large deposit of fine particles was observed at the botton of the beaker. On organoleptic evaluation, a powdery feel in the mouth was noted.

Peas have been partially freeze dried to 7.5% moisture, equilibrated for 2 hours and compressed. This method reduced the I_f considerably (I_f 1.4). However, it was difficult to determine the freeze drying end point and several attempts had to be made to reach an acceptable moisture level. The cohesion of this bar was poor as compared with water sprayed samples.

2. Glyerin Treatment

Glycerin has also been found to be an effective agent to reduce the fragmentation due to compression. Although the I_f obtained with a 10% level of glycerin ($I_f = 2.8$), shown in Table VI, is higher than the 1.2 obtained with the water treatment, the glycerin treated product is very acceptable with little fragmentation.

In this method, a sample of freeze dried cooked peas of less than 2% moisture weighing 85 grams was sprayed uniformly with 15 grams of glycerin, and mixed gently for two minutes. The treated peas were then heated in a still air oven at 80°C for 1½ hours, gently stirring every 15 minutes. Samples of approximately ten grams were then compressed to a pressure of 1100 psig and held for five seconds using a hydraulic press with preheated die and thermostatically controlled plates at 60°C. (The resulting bar was greener and glossier than the compressed bar treated with water). Rehydration rate for the compressed glycerin treated bar in boiling water was the same as for an untreated, uncompressed sample. The density of the treated bar was 0.73 gm/cc. as compared to a bulk density of 0.16 gm/cc. for uncompressed peas. The bar withstood more than 10 drops in the "falling ball test". Peas containing glycerol have been observed[3] to lose their

(3) V-339, Rpt. 5 (Final) Denison Research Foundation, Contract: DA19-129-qm-1630, 15 June - 14 June 1961, p. 27.

surface color in a short time. This effect is apparently a photo-sensitive reaction, since work on this project shows that color loss can be eliminated by keeping the glycerol-treated peas in containers which prevent or reduce their exposure to light.

3. Other Methods

Treating the freeze-dried peas with propylene glycol will also reduce the fragmentation; however, the bitter flavor is not as compatible as the sweet flavor of the glycerin. Ethyl alcohol instead of water can be used to reduce the fragmentation. With the ethyl alcohol, however, the I_f is not as low as water treated peas and the peas must be compressed at an elevated temperature. The alcohol would be easier to remove after compression than water. Further work on the alcohol treatment was discontinued, however, because of the success of the water treatment.

STORAGE STABILITY

1. Glycerin Treatment

The treatment of peas with glycerin does not affect their stability when stored for six months at cycling (0-40°F) and at 70°F temperatures However, changes in flavor after 70°F storage were observed in treated as well as untreated peas. Glycerin treated peas stored at 100°F are unacceptable after six months storage due to excessive browning. Table VI gives the pertinent data obtained from the storage evaluation.

TABLE VI

THE EFFECT OF VARIOUS TREATMENTS ON INDEX FRAGMENTATION OF PEAS

Sample	Treatment	Compression Temp.	I_f
1	Non-Compressed	——	1
2	Untreated-Compressed	20°C	18.6
3	15% Glycerin	60°C	2.0
4	10% Glycerin	60°C	2.8
5	10% Ethyl Alcohol	20°C	5.6
6	10% Ethyl Alcohol	40°C	5.2
7	5% Water	20°C	1.2

TABLE VII

STORAGE STABILITY EVALUATION OF PEAS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
PC	Initial	1	6.65	-	1.4	.16	-	1-3	T	T	T	T	5	-
No	Cycling	1	6.70	-	"	"	-	1-5	T	T	T	T	5	-
Treatment	70°	1	6.88	-	"	"	-	1-5	Sl. Loss	Sl.Tea	T	T	4	-
Non-Compressed	100°	1	6.65	-	"	"	-	1-5	" "	" "	T	T	4	-
PCP	Initial	16	6.68	0	1.1	.58	-	1-3	T	T	Powdery	T	1	-
No	Cycling	16.2	6.90	0	1.2	"	-	1-3	T	T	"	T	1	-
Treatment	70°	16.2	6.82	0	1.5	"	-	1-3	Sl.Loss	Sl.Tea	"	T	1	-
Compressed	100°	13.7	6.72	0	1.6	"	-	1-3	Sl.Loss	Sl.Tea	Sl.Tougher	T	1	-
P15G	Initial	2.8	6.65	10+	1.3	.73	Crumbles	1-3	Sweeter	T	) More	T	4	-
15% Glycerin	Cycling	3.1	6.90	10+	1.3	.75	"	1-3	"	T	) Tender	T	4	-
Compressed	70°	3.2	6.90	10+	1.4	.71	"	1-3	"	Sl. Burnt	) Than PC	T	3	-
	100°	2.5	6.28	9	1.4	.72	Tough Crumbles	1-3	Strong Scorch	Strong Burnt	Sl. Tougher	Brn.	1	UA

Notes: T = Typical.
UA = Unacceptable.
Overall Rating; 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

Not included in Table VII are rehydration ratio, microbiological examinations and appearance of bars. Generally, these factors were not affected by storage. Treating peas did not affect microbial counts nor decrease rehydration ratio. Complete details are given in previous progress reports.

2. Water Treatment

A limited storage stability study (organoleptic evaluation only) indicated that water treatment of peas had no effect on stability of the peas at 70°F and 100°F. This is a considerable improvement over glycerin treated peas which were organoleptically unacceptable after six months storage at 100°F.

II. SHRIMP

A. REDUCTION OF FRAGMENTATION

The freeze dried shrimp used for the purposes of this contract were commercial whole shrimp (26/29 per lb. when rehydrated) obtained from United Fruit and Food Company and had a moisture content of 1.6%. Freeze-dried shrimp are very fragile; therefore, compression of the shrimp into food bars causes considerable fragmentation. This fragmentation adversely affects the palatability of the rehydrated shrimp producing a high percentage of fines and breaking down the texture of the larger pieces to a softer, more fibrous texture. Reduction of fragmentation has been achieved by use of glycerin, propylene glycol or water.

1. Glycerin Treatment

Treating shrimp with glycerin at levels of 10 to 20% will soften the texture resulting in a reduction of the fragmentation due to compression. It was found that spraying was the most efficient method of applying the glycerin. Best results can be obtained with glycerin if the shrimp is compressed at 60°C. This was done by preheating the shrimp in an oven and compressing with heated molds and compression plates. Some typical values which indicate the degree of reduction in fragmentation achieved by glycerin is given in Table VIII. Samples of shrimp treated with glycerin were placed in storage.

TABLE VIII

THE EFFECT OF VARIOUS TREATMENTS ON THE I_f OF FREEZE DRIED SHRIMP

Sample	Treatments	I_f
1	Control - No compression.	1
2	Untreated, compressed at R.T.	7.6
3	Untreated, compressed at 60°C.	5.6
4	20% Glycerin-not sprayed on, compressed at 60°C.	3.8
5	10% Glycerin-sprayed on, compressed at 60°C.	[illegible].6
6	15% " " " " " "	1.6
7	10% Propylene Glycol-sprayed on, compressed at 60°C.	1.5
8	15% Propylene Glycol-sprayed on, compressed at 60°C.	1.1
9	5% Propylene Glycol-sprayed on, compressed at 60°C.	1.9

2. Propylene Glycol

The use of propylene glycol resulted in far greater reduction of fragmentation than equivalent levels of glycerin (Table VIII). A level of 5% propylene glycol reduces the fragmentation to the same degree as 15% glycerin. Compression at an elevated temperature (60°C) was necessary to achieve maximum reduction of fragmentation. Also spraying was found to be the most efficient means of application. The storage stability of propylene glycol treated shrimp is given below.

3. Other Methods

Ethyl alcohol (15%) was also found to be effective in reducing fragmentation of shrimp. The shrimp was preheated to 60°C, mixed with alcohol and then compressed. The heating is necessary to achieve maximum reduction of fragmentation. The time lapse between the compression of three replications, however, was sufficient to allow much of the alcohol to vaporize.

This lowered the alcohol concentration and caused rapid cooling of the shrimp. One or both of these factors were probably the reason for the progressively greater fragmentation of successive samples from the same batch (in sequence = 1.4, 1.6, and 3.8). This problem was not encountered when using the other plasticizers (propylene glycol and glycerin). Alcohol treatment requires evaporating off the alcohol after compression which is not necessary with glycerol or propylene glycol.

Treating the shrimp with water is another effective means of reducing the I_f of compressed shrimp. An I_f of 1.4 was obtained by spraying the shrimp to a moisture level of 7.5% before compression. The rehydration time for water treated shrimp is 30-40 minutes and the shrimp remained flat after rehydration. The redrying step is required to reduce the moisture to a level compatible with prolonged stability. Further work on the water treatment is necessary to improve the rehydration rate of the shrimp.

E. STABILITY OF SHRIMP

1. Storage

Samples of treated shrimp and non-treated shrimp were placed in storage for six months at temperatures specified in the contract (70°, 100° and cycling). These samples included compressed shrimp with 5% propylene glycol treatment, 15% glycerin treatment, and non-treated shrimp with and without compression. The treated samples were compressed at 60°C.

Evaluation of these samples was made initially and after six months storage. Complete data from these evaluations are given in the progress reports for this contract. However, Table IX gives some of the more important results. Not included in this table is rehydration ratio, microbiological examination and appearance of bar. Generally these factors were not affected by storage. The microbiological tests indicated that treating the shrimp did not increase microbiological activity.

TABLE IX

STORAGE STABILITY EVALUATION OF SHRIMP

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
SHC	Initial	1	6.70	-	2.2	0.2	-	10	T	T	T	T	5	-
No	Cycling	1	6.89	-	1.9	-	-	10	T	T	T	T	5	-
Treatment	70°F	1	6.89	-	1.8	-	-	10	Sl. Loss	Sl. Loss	T	T	4	-
Non- Compressed	100°F	1	6.78	-	1.9	-	-	10	Mod. Loss	" "	T	T	4	-
SHCP	Initial	11.4	6.61	2	2.2	.67	Crumbles	3	T	T	Powdery	T	1	-
No	Cycling	13.5	6.80	3	1.8	.58	"	3	T	T	"	T	1	-
Treatment	70°	10.7	6.90	1	2.1	.57	"	3	Sl. Loss	Sl. Loss	"	T	1	-
Compressed	100°	13.8	6.87	2	1.9	.55	"	3	Mod. Scorch	Mod. Loss	"	Lighter	1	-
SH5PG	Initial	2.8	6.75	8	2.0	.67	"	4	T	T	T	T	5	
5% Propylene	Cycling	1.7	7.26	8	1.7	.55	"	7	T	T	T	T	5	
Glycol	70°F	2.9	7.30	8	1.7	.57	"	7	Sl. Loss	Sl. Loss	T	T	5	
Compressed	100°F	2.1	7.26	9	1.4	.57	"	7	Mod. Scorch	Mod. Burnt	T	Brn.	2	BA
SH15G	Initial	3.0	6.61	10+	2.2	.67	"	4	Sweeter	T	T	T	4	-
15%	Cycling	2.3	7.30	10+	2.2	.67	"	20	"	T	T	T	5	-
Glycerin	70°F	3.8	7.20	10+	2.2	[illegible]	"	20	Strong Scorch	Strong Burnt	T	Brn.	1	UA
Compressed	100°F	[illegible]	[illegible]	1	[illegible]	.62	"	20	Strong Scorch	Strong Burnt	T	Brn.	1	UA

Notes: T = Typical; UA = Unacceptable; BA = Borderline Acceptability.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

III. CORN

A. REDUCTION OF FRAGMENTATION

Fragmentation of compressed, freeze dried corn has been reduced by treatment with either propylene glycol or water. The propylene glycol treated corn has very poor stability at 100°F. The water treated corn, however, has good stability at all temperatures investigated.

1. Water Treatment

It has been shown experimentally that spraying freeze dried corn with water at levels of 5-10% will greatly reduce the fragmentation with 12% resulting in an I_f of 1.0 (Table X) essentially the same I_f by definition as the non-compressed corn. Higher levels of water, however, greatly decreased the rehydration rate while low levels of water increased the rehydration rate but decreased the cohesion. In order to make a bar with a low I_f, cohesive enough to withstand normal handling and that will rehydrate within a practical time limit, a special technique using gum arabic was devised. In this method, there were used freeze dried loose kernels of sweet corn of the usual size (e.g., ½" x 3/8"), which had been blanched in boiling water for about 3 minutes before freeze drying and which had a moisture content of 1.4%. The bulk density of a mass of the freeze dried kernels was 0.19 and the apparent density of the individual kernels was 0.36.

The dried kernels were sprayed with a fine mist of a sufficient amount of a 10% aqueous solution of gum arabic to produce a product containing 10.4% water and 1% gum arabic. The kernels were then allowed to stand for 30 minutes on a tray open to the atmosphere. At this stage, the surface of the corn appeared dry, while the interior of the kernel contained sufficient moisture so that the kernel would yield without breaking when squeezed between one's fingers. Thereafter, the surfaces of the kernels were sprayed uniformly with a fine mist of an additional ½% (based on the weight of the previously moistened corn) of the same 10% gum arabic solution.

TABLE X

REDUCTION OF FRAGMENTATION OF CORN

Treatment	I_f
Non-treated, non-compressed	1.0
Non-treated, compressed	5.5
5% Water, compressed	1.1
7.5% Water, compressed	1.0
10.0% Water, compressed	1.0
5% Propylene Glycol	1.4

Twelve grams of the kernels were then placed in a Carver hydraulic press and subjected at room temperature to a pressure of 1100 psig to produce a compressed bar whose thickness (in the direction the pressure was applied) was about 0.55" and which had parallel top and bottom faces each 2 square inches in area. The press cycle was such that it took 5 seconds to reach the pressure of 1100 psig which was maintained for another 5 seconds, after which the press was opened.

In the compressed bar the kernels adhered to each other. The bar had a relatively smooth surface. While the kernels were individually visible, the crevices or depressions in the surface where the kernels met each other were very shallow (e.g. less than 1 mm). The compressed bar was dried in a vacuum oven under a pressure of about $1\frac{1}{2}$" Hg absolute at oven temperature of 60°C. for 5 hours to reduce the moisture content to 1.5%. The resulting dried bar had substantially the same appearance and occupied substantially the same volume as the compressed bar before drying and had a density of 0.66 g/cc. It was composed of dried flattened kernels which retained their original yellow color. The bar could be separated into the individual kernels with the fingernails. The bar withstood 3 drops in a "falling ball test", described previously, without cracking.

The dried bar was fully rehydrated within 5 minutes by placing it in a beaker containing 150 cc. of boiling water and allowing to stand without further heating. It separated into its individual kernels without agitation and the kernels recovered from the flattened state to substantially their original size and shape.

The flavor and texture of the product were substantially the same as that obtained by fully rehydrating, in the same way, the original freeze dried corn without any intermediate steps of partial rehydration, compression and drying. Substantially no visible fines were observed. When this experiment was repeated, except that the second spraying was omitted, the kernels would not retain the bar shape after compression but broke up into individual unfragmented kernels when it was attempted to remove the bar from the mold. When gum arabic is omitted from the water, the bar is less cohesive and less resistant to cracking in the "falling ball test".

By comparison, untreated freeze dried corn breaks up into powder upon compression, losing entirely its initial shape and form. On rehydration, a large deposit of fine particles is observed at the bottom of the beaker.

2. Propylene Glycol Treatment

Treating the freeze dried corn with propylene glycol prior to compression significantly reduced the fragmentationdue to compression. Optimum level and temperature of compression were selected as 5% at 60°C compression temperature. This treatment reduces the I_f amount from 5.5 to 1.4. The compressed bar rehydrates quickly in boiling water, without agitation and regained the shape and appearance of uncompressed corn with few fine particles being observed.

In this method eighty grams of freeze dried corn were sprayed uniformly with four grams of propylene glycol and heated in a still air oven at 60°C for one hour. Samples of approximately 11 grams were then compressed to a pressure of 1100 psig and held for 5 seconds using heated die and plates at 60°C.

The density of the compressed treated bar was 0.7 gm/cc as compared to a bulk density of 0.19 for untreated uncompressed corn. The bar was sufficiently cohesive to withstand three impacts in the "falling ball test". Similar rehydration rates were found for the treated bar and untreated uncompressed corn.

As mentioned above and again later in detail the propylene glycol treated samples store very poorly at 100°F. The advantage of this treatment, however, is that a redrying step (necessary in the water treatment) after compression is not required.

Another experiment in which the propylene glycol was removed from the compressed bar indicated that this could be used to increase stability of the bar. A propylene glycol treated compressed bar was placed in a freeze dryer (not frozen) and subjected to 80°F heat from radiant plates for 1-5 hours with vacuum less than 10 microns and condenser temperature at -90°F. Every hour a sample was removed from the freeze dryer and packaged in poly-foil-poly pouches. Storage of these samples for six months indicated that samples remaining in the freeze dryer three or more hours did not become brown. Propylene glycol samples put into the vacuum chamber less than three hours had off flavor and color due to browning with the greatest browning observed in control samples (not subjected to propylene glycol removal by vacuum). Rancidity was not observed in any of the propylene glycol samples.

Since a redrying step is necessary for propylene glycol samples to obtain good stability, there seems to be no advantage to this method over water treated samples which also need redrying.

B. STABILITY OF CORN

1. Water Treatment

A complete storage series has been run on propylene glycol treated corn as noted below. The water treatment was developed later and, since no residual additive was involved, organoleptic evaluations were felt to be all that were required within the terms of the contract.

In the limited storage test it was found that organoleptic qualities of water treated samples compared favorably with the untreated samples with no flavor changes noted after six months storage at 70°F, 100°F, and cycling (35° - 0°F). Occasional samples showed rancidity but, since the corn was obtained from commercial sources, it is believed that repackaging of the corn was responsible for this and that freshly prepared nitrogen packed freeze dried corn would not be expected to go rancid.

2. Propylene Glycol Treatment

Data in Table XI indicate that treating corn increases storage stability of samples at cycling and 70°F. Treated samples rated better with respect to fresh corn flavor retention than did the untreated corn both compressed and non-compressed. At 100°F all samples were unacceptable because of excessive browning in treated samples and oxidative rancidity in untreated samples. Generally these factors were not affected by storage. Treating corn did not affect microbiological counts nor decrease rehydration ratio. Complete details are given in previous progress reports.

TABLE XI

STORAGE STABILITY EVALUATION OF CORN - 6 MONTHS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
CC	Initial	1	7.3	-	1.4	.19	-	5	T	T	T	T	5	-
No	Cycling	1	-	-	1.4	-	-	5	Sl.Loss	T	T	T	5	-
Treatment	70°F	1	-	-	1.4	-	-	5	Starchy	Starchy	T	T	3	-
Non-Compressed	100°F	1	-	-	1.4	-	-	5	Strong Rancid	Strong Rancid	T	W	1	UA
CCP	Initial	5.5	7.3	0	1.4	.65	-	5	T	T	Powdery	T	1	-
No	Cycling	8.5	7.5	0	1.7	-	-	5	T	T	"	T	1	-
Treatment	70°F	10.1	7.6	0	1.5	-	-	5	Starchy	Starchy	"	T	1	-
Compressed	100°F	7.9	7.2	0	1.8	-	-	5	Strong Rancid	Strong Rancid	"	White	1	UA
C5PG	Initial	1.1	7.3	3	1.5	.70	Crumbles	5	T	T	T	T	3-4	-
5% Propylene	Cycling	1.3	7.6	3	1.2	.77	"	5	T	T	T	T	3-4	-
Glycol	70°F	1.4	7.5	6	1.3	.77	"	5	Sl.Burnt	Sl.Burnt	T	T	4	-
Compressed	100°F	1.5	6.9	3	1.2	.77	"	5	Strong Burnt	Strong Burnt	T	Yellow Brown	1	UA

Notes: T = Typical.
UA = Unacceptable.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

IV. CHICKEN

A. REDUCTION OF FRAGMENTATION

The use of propylene glycol or glycerin also proved effective in reducing the fragmentation of chicken. Chicken bars formed without treatment had no cohesion and when rehydrated had a powdery mouthfeel due to excessive fines produced by the compression.

1. Propylene Glycol and Glycerin Treatment

The fragmentation of chicken bars was reduced from an I_f of 4.5 for untreated chicken to 1.2 and 1.6 for propylene glycol- and glycerin-treated chicken, respectively (10% level). The method was the same for both treatments, In each method, 90 g of screened ¼" freeze dried chicken cubes containing less than 2% moisture were sprayed uniformly with 10 grams of the additive and heated in a still air oven at 60°C for one hour. Samples of approximately 10 grams were then compressed to a pressure of 1100 psig for a period of 5 seconds using a die and plates heated to 60°C.

2. Other Methods

Treating chicken with water prior to compression greatly reduces the fragmentation. However, because of the good results obtained with glycerin-treated chicken in storage stability studies, further work on water treatment was discontinued.

B. STORAGE STABILITY

The data in Table XII indicate that glycerin and untreated chicken had excellent stability at cycling and 70°F storage temperatures. The propylene glycol sample scored lower at 70°F storage because of browning.

At 100°F storage temperatures, the propylene glycol treated sample was unacceptable and the other samples were acceptable but received lower flavor score.

Since no significant changes after storage were observed in the microbiological examinations and the rehydration ratios, the results are not included in Table XII. The number of microorganisms in all samples remained low throughout the six months storage with no significant

STORAGE STABILITY EVALUATION OF CHICKEN - 6 MONTHS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time (min)	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
CHC	Initial	1	5.0	-	3.1	.23	-	3.5	T	T	T	T	5	-
No	Cycling	1	6.1				-	"	T	T	T	T	5	-
Treatment	70°F	1	6.0	-	-	-	-	"	T	T	T	T	5	-
Non-	100°F	1	5.0	-	-	-	-	"	Cardboard	No	T	T	3	-
Compressed										Chicken				
CHCP	Initial	4.5	5.5	0	3.1	.65	-	3	T	T	Sl. Powdery	T	4	-
No	Cycling	3.9	6.1	0	3.6	-	-	3	T	T	" "	T	4	-
Treatment	70°F	3.7	6.0	0	3.6	-	-	3	T	T	" "	T	4	-
Compressed	100°F	3.5	5.9	0	3.8	-	-	3	Canned	Lack	" "	T	3	-
									Chicken	Fresh				
										Aroma				
CH10PG	Initial	1.2	5.5	10+	3.8	.72	Crumbly	5	T	T	T	T	5	-
10%	Cycling	1.2	6.1	1	3.6	.78	-	"	T	T	T	T	5	-
Propylene	70°F	1.4	6.0	1	3.5	.76	-	"	Bitter,	Sl. Burnt	T	T	4	-
Glycol									Sl. Scorch					
Compressed	100°F	1.3	5.9	1	3.4	.78	-	"	Off, Strong	Strong	T	Reddish	1	UA
									Scorch	Burnt				
CH10G	Initial	1.6	5.6	10+	3.9	.83	Crumbly	5	T	T	T	T	5	-
10%	Cycling	1.8	6.1	10+	3.6	.84	-	"	T	T	T	T	5	-
Glycerin	70°F	1.7	6.0	10+	3.8	[illegible]	-	"	Sl. Loss	T	T	T	5	-
Compressed	100°F	1.4	6.1	10+	3.6	.81	-	"	Scorched	Burnt	T	Reddish	3	-

Note: UA = Unacceptable.
T = Typical.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

differences observed because of treatments on storage conditions. Also, there was no change after storage in the appearance of the bars (shape, cracking and surface) other than color which is reported in Table XII. Complete results are given in Progress Report No. 5.

V. PEACHES

The dried peaches used for the purpose of this contract were commercial halves (ca. 12% moisture) obtained from Seeman Bros., Inc. These peaches, compressed at 1100 psi, did not present a fragmentation problem. Organoleptic analyses of compressed vs. uncompressed peaches indicated only that the compressed peaches may have a slightly softer texture but were definitely not less objectionable. Visual inspection of the peaches did not show any damage to the skin or interior of the peaches that was peculiar to the compressed peaches. However, the presence of a small amount of fines was observed in the rehydration liquid of the compressed sample. This increase of fines is reflected in the I_f of 1.4 for the compressed peaches. It was found that even this amount of fines could be reduced, however, by compressing the peaches at 60°C to yield an I_f of 1.2.

Since peaches do not require treatment to obtain an acceptable bar, storage studies on this item were omitted.

VI. RICE

Precooked rice used for the purpose of this contract contained 8% moisture. The commercial product with 8% moisture (General Foods' Minute Rice) was dried to 3% moisture in an air oven prior to use. In the case of rice to be treated with water prior to compression as described below, the predrying step was omitted. Upon compression, the dried rice underwent severe fragmentation with no grains of rice remaining on the top screen in the fragmentation test. (I_f = 4.7).

A. REDUCTION OF FRAGMENTATION

1. Effect of Moisture on Index of Fragmentation

The fragmentation of rice was substantially reduced by spraying the rice with water. The moisture level of 17.5% was selected as optimum (Table XIII). A lower level of moisture increased the fragmentation and considerably more moisture was needed to reduce the fragmentation significantly.

Spraying the rice with water to a moisture level of 17.5% and compressing immediately resulted in an extremely cohesive bar which required over an hour to rehydrate. The reason is believed to be due to the sticky moist surface of the rice grains. Allowing the rice to equilibrate at room temperature for at least 3½ hours allows the surface to dry enough so that subsequent compression resulted in a bar which rehydrates in 10 minutes.

The use of a fan was found to be a more efficient way of reducing the stickiness of the surface of the rice grains. Using this method, rice can be compressed 5 minutes after spraying is completed. Bars made in this way rehydrate within 5 minutes but have poor cohesion. It was found that an optimum level (10%) of gum arabic dispersed in the water sprayed on the rice successfully increased the cohesion without decreasing the rehydration rate.

Samples of rice, using the gum arabic solution and fan method, were made and evaluated for six months' storage stability. The method of preparation and physical characteristics are given below.

The rice was sprayed with a 10% gum arabic solution to a final moisture of 17.5. The sprayed grains were then spread out under a fan 12" above the rice for 5 minutes in order to dry the outermost surface of the grains. Samples of approximately 20 grams were then compressed and dried in a vacuum oven for 5 hours at an oven temperature of 70°C to a final moisture of 3.9%.

The treated bar had a density of 0.71 gm/cc; the bulk density of the original Minute Rice was 0.39 gm/cc. and the apparent density of each of the individual Minute Rice grains was about 0.77 gm/cc. In the "falling ball" test, the treated bar was sufficiently cohesive to withstand three impacts. The rehydration rate in boiling water for the treated, compressed bar and untreated, compressed bar was the same. Separation and rehydration of the rice grains occurred within 5 minutes.

2. <u>Propylene Glycol, Glycerin and Other Treatments</u>

Treatment with glycerin, propylene glycol, ethanol and cottonseed oil, even when allowed to equilibrate for as long as 14 days, did not reduce the fragmentation significantly. Combinations of these treatments with heating before and during compression was ineffective. It is noteworthy that none of these agents with which the rice was treated as mentioned above produced any noticeable softening of the texture of the dry rice by organoleptic examination.

TABLE XIII

MOISTURE LEVEL - vs. INDEX OF FRAGMENTATION OF RICE

Sample No.	Total Moisture Level	I_f
1-79A-7A, B	5.0%	4.8
1-79A-1A, B	8.2%	3.8
1-79A-2A, B	9.7%	2.8
1-79A-3A, B	12.6%	2.2
1-79A-4A, B	14.6%	2.2
1-79A-5A, B	16.7%	1.9
1-79A-6A, B	17.5%	1.7
1-79B-8A, B	19.0%	1.7
1-79B-9A, B	24.2%	1.8
1-79B-10A, B	28.0%	1.2

B. PRODUCT STABILITY

1. Storage Stability

Data for storage stability evaluations of the treated rice bars are tabulated in Table XIV. It is seen that the water treatment described above did not affect storage stability at any of the temperatures investigated, indicating complete success for this product in all phases of evaluation.

TABLE XIV

STORAGE STABILITY EVALUATION OF RICE - 6 MONTHS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
RC	Initial	1	6.3	-	2.1	0.39	- TOO HARD TO CHEW -	3-4	T	T	T	T	5	-
No	Cycling	1	6.3	-	-	-		"	T	T	T	T	5	-
Treatment	70°F	1	6.4	-	-	-		"	Sl. Loss	T	T	T	4	-
Non-	100°F	1	6.3	-	-	-		"	T	T	T	T	4	-
Compressed														
RCP	Initial	4.7	6.2	0	2.1	-		"	T	T	Powdery	T	1	-
No	Cycling	5.0	6.3	0	3.3	-		"	T	Sl. Pungent	"	T	1	-
Treatment	70°F	4.8	6.4	0	3.5	-		"	T	Sl. Loss	"	T	1	-
Compressed	100°F	4.7	6.3	0	1.5	-		"	Sl. Off	T	"	T	1	-
R10W	Initial	1.4	6.2	3	3.9	0.71		"	T	T	VERY SLIGHT-FRAGILE	T	4	-
10% Water	Cycling	1.3	6.2	4	3.9	0.74		"	T	T		T	4	-
Compressed	70°F	1.3	6.3	4	2.5	0.76		"	T	T		T	4	-
	100°F	1.4	6.2	4	3.0	0.67			T	T		T	4	-

Note: T = Typical.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

VII. ONIONS

The dried onions used for the purpose of this contract were commercial "chopped onions" (3% moisture) obtained from Basic Vegetable Products, Inc.

A. REDUCTION OF FRAGMENTATION

Commercially dried chopped onions vary in size considerably. The fragmentation of compressed onions with no treatment is not as obvious as it is with some other foods because of this variation, and the fact that even though the larger pieces are reduced in size upon compression, there is not a great increase of very fine particles. However, the appearance after compression and rehydration of untreated chopped onions resembles that of a much finer grade of chopped product, than the rehydrated control. The I_f of the compressed onions with no treatment was calculated to be 2.7.

1. Water Treatment

Spraying onions with water was found to be highly successful in reducing fragmentation. Moisture levels and equilibration times were varied between 6 and 12%, and 2 and 6 hours, respectively, to determine the optimum combination. Considering minimum moisture and equilibration time as a matter of practicality, a 9% moisture level with three hours equilibration was considered optimum. An I_f of 1.3 was attained using this treatment. Results are tabulated in Table XV.

Upon compression, whether treated or not, the onions exhibit an undesirable metallic taste. Cottonseed oil, hydrogenated vegetable oil, and Durkex 500 (blend of vegetable oils) were sprayed on the onions both prior to and after spraying with water. All oils were found to be effective in considerably reducing the off-flavors due to compression, with a slight flavor preference for samples sprayed prior to water treatment rather than after water treatment. Rehydration was also enhanced with use of the oils. Index of Fragmentation was not affected. For these reasons, onions for storage evaluation were sprayed with a vegetable oil (Durkex 500) to a level of 4%, allowing one hour equilibration before treating with water (9% level).

TABLE XV

REDUCTION OF FRAGMENTATION OF COMPRESSED ONIONS

Additive Level	Temp. of Compression	Equilibration	I_f
6% Moisture	R. T.	2 hrs.	1.4
" "	" "	4	1.3
" "	" "	6	1.5
9% Moisture	" "	2	1.3
" "	" "	3	1.3
" "	" "	4	1.1
" "	" "	6	1.0
12% Moisture	" "	2	1.1
" "	" "	4	1.0
" "	" "	6	1.0
10% Propylene Glycol	50°C	20	1.2
10% Glycerin	60°C	20	1.2

2. Propylene Glycol and Glycerin Treatments

Treating the onions with propylene glycol or glycerin to a level of 10% reduced the I_f to 1.2. The treatment, however, required 20 hours of equilibration and compression at 60°C. Off flavors that developed due to compression could not be eliminated by treatment with oil as was possible with the water treatment.

B. PRODUCT STABILITY

Onions for stability tests were treated with vegetable oil to a level of 4%, equilibrated for one hour, and then sprayed with water to a level of 9%. After three more hours equilibration, the samples were compressed and redried in a vacuum oven at 50°C for 5 hours. Control samples (not treated or compressed) and compressed samples (not treated, but compressed) were also placed in storage for comparison. Storage stability evaluations for initial and six months storage are presented in Table XVI.

STORAGE STABILITY EVALUATION OF ONIONS - 6 MONTHS

Code & Treatment	Storage Condition	IT	pH'	Drop Test	Moisture (%)	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
OC	Initial	1.0	5.1	-	3.5	0.4	- NOT APPLICABLE -	1-2	T	T	T	T	5	-
No	Cycling	-	5.6	-	-	-		"	T	T	T	T	5	-
Treatment	70°F	-	5.6	-	-	-		"	Sl. Loss	T	T	T	4	-
Not Compressed	100°F	-	5.5	-	-	-		"	Bitter Scorched	T	T	Lt. Brn.	2	BA
OCP	Initial	2.6	5.1	1	3.4	0.9		"	Sl. Metallic	T	Frag.	T	4	-
No	Cycling	2.7	5.6	0	4.3	-		"	Weak Off	T	"	T	3	-
Treatment	70°F	2.6	5.6	0	4.1	-		"	Med. Off	T	"	T	2	BA
Compressed	100°F	2.7	5.4	0	4.0	-		"	Med. Off, Scorched	T	"	Lt. Brn.	1	UA
OSW	Initial	1.3	5.1	10+	3.9	1.0		"	T	T	T	T	3	-
9% Wat 4% Oil	Cycling	1.1	5.6	10+	3.6	1.1		"	Sl. Burnt Oil	Burnt	T	T	3	-
Compressed	70°F	1.3	5.6	10+	2.7	1.1		"	Med Burnt Oil	Burnt	T	T	2	UA
	100°F	1.3	5.3	10+	3.0	1.1		"	Strong Burnt Oil	Burnt	T	Dk. Brn.	1	BA

Notes: T = Typical; UA = Unacceptable; BA = Borderline Acceptability.

Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

Although in virtually all cases, the flavor was adversely affected by storage, the treatment itself contributed a burnt oil flavor to the onions. The treatment also affected the aroma of the product which became more objectionable at higher storage temperature. The browning reaction observed at 100°F for the control and untreated samples was intensified by the treatment used to reduce fragmentation.

VIII. GROUND COOKED BEEF

The beef used for the purpose of this contract was cooked ground (¼" plate) freeze dried beef (2-3% moisture) from Wilson & Company.

A. REDUCTION OF FRAGMENTATION

1. Propylene Glycol Treatment

Heat combined with glycerin or propylene glycol has resulted in a considerable reduction of fragmentation (Table XVII). However, organoleptic evaluations of treated beef bars indicated that glycerin was incompatible with the beef flavor while levels of up to 10% propylene glycol were considered compatible. Therefore, samples treated with 10% propylene glycol, equilibrated one hour at 60°C and compressed with heated molds and plates (60°C) were placed in storage for evaluation after six months.

2. Water Treatment

Water is also effective in reducing the fragmentation of beef. As shown in Table XVII, spraying the beef to increase the moisture level by 10% and compressing at 60°C resulted in an I_f of 1.4. The water treatment was developed after the propylene glycol treatment; therefore, storage evaluations have not been made on the water treated samples. Further work is necessary to improve the poor rehydration rate of the water treated samples. However, because of the poor storage stability of propylene glycol samples, it is believed that the water treatment is the most promising approach at the present time.

TABLE XVII

EFFECTS OF VARIOUS TREATMENTS ON I_f OF BEEF

Sample	Treatment	I_f
1	Control - no compression.	1
2	Untreated - compressed at R.T.	5.9
3	Untreated - compressed at 60°C	5.0
4	15% Glycerin - compressed at 60°C	3.1
5	15% Propylene Glycol - compressed	1.6
6	10% Propylene Glycol - compressed	3.4
7	5% Water; compressed at R.T.	1.8 - 1.9
8	7.5% Water; compressed at R. T.	1.9 - 2.0
9	10% Water; compressed at R.T.	1.7 - 1.8
10	10% Water; compressed at 60°C	1.4

B. STORAGE STABILITY

The 10% propylene glycol treatment affected storage stability at 70°F and 100°F causing a browning reaction. Samples not treated and stored at 100°F were also considered unacceptable because of a high level of rancidity. Complete evaluation is reported, but flavor changes are most significant.

Since no significant changes after storage were observed in the microbiological examinations and the rehydration ratios, the results are not included in Table XVIII. The number of microorganisms in all samples remained low throughout the six months storage with no significant differences observed because of treatments or storage conditions. Also, there was no change after storage in the appearance of the bars (shape, cracking and surface) other than color which is reported in Table XVIII. Complete results are given in a previous progress report (No. 5).

TABLE XVIII

STORAGE STABILITY EVALUATION OF GROUND COOKED BEEF - 6 MONTHS

Code & Treatment	Storage Condition	I_Y	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
BC	Initial	1	5.4	-	1.1	.32	-	5	T	T	T	T	4	-
No	Cycling	1	-	-	1.1	-	-	20	T	T	T	T	4	-
Treatment	70°F	1	-	-	1.1	-	-	20	T	T	T	T	4	-
Non-	100°F	1	-	-	1.1	-	-	20	Rancid	Rancid	T	T	1	UA
Compressed														
BCP	Initial	2.6	5.4	3	1.1	.94	Extremely Hard Inedible Pieces	5	T	T	Powdery	T	1	-
No	Cycling	2.6	5.7	3	0.7	1.01		5	Inferior	Inferior	"	T	1	-
Treatment	70°F	2.5	5.6	4	0.9	1.01		5	Beef	Beef	"	T	1	-
Compressed	100°F	2.2	5.6	5	0.8	0.99		7	Rancid	Rancid	"	T	1	UA
B10PG	Initial	1.7	5.4	10	1.8	0.95	Extremely Hard Inedible Pieces	5	T	T	More Tender	T	3	-
10%														
Propylene	Cycling	1.4	5.7	3	1.6	0.95		5	T	T	"	T	4	-
Glycol	70°F	1.4	5.6	4	1.8	0.91		5	Scorch	Burnt	"	T	2	-
Compressed	100°F	*	5.6	9	1.5	0.95		7	Strong Scorch	Strong Burnt	"	Yellow	1	UA

Notes: T = Typical; UA = Unacceptable; * = Did Not Rehydrate.

Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

IX. BEEF STEW

The beef stew (LP/P. DES C-187-62) used for this investigation consisted of freeze dried beef, potatoes, carrots and peas along with spices and gravy. The formula is given above (MATERIALS AND METHODS, I., G., BEEF STEW).

Upon compression of a sample of beef stew with no treatment, all the vegetables and the meat were very badly fragmented. (I_f of 5.0).

A. REDUCTION OF FRAGMENTATION BY WATER TREATMENT

Water treatment of beef stew was found to be so successful in reducing the fragmentation that no other additives were investigated.

During the early stages of the investigation, it was concluded that the gravy mix should not be treated together with the other components, but added just prior to compression. Spraying the beef stew with the gravy mix present produced an unacceptable bar. The gravy mix absorbed most of the water causing incomplete rehydration and high fragmentation of the meat and potatoes.

Observations were made on each component separately to determine minimum levels of moisture required to reduce fragmentation to acceptable levels. The optimum level found for each component with one hour equilibration is tabulated below.

Component	% Moisture Level Added
Potatoes	15%
Carrots	5%
Peas	5%
Meat	15%

Spraying all the components together, excluding the gravy mix, to an overall added level of 10% of water with one hour equilibration time reduced fragmentations to an acceptable level (I_f = 1.6). It was found that enough moisture was added overall to meet the minimum levels for each component except meat as stated in the above table. This was established by weighing each component before and after spraying and equilibration. A typical test is shown below

Component	Wt. Before Spraying (gms.)	Wt. After Spraying (gms.)	Approx. % Added Moisture
Meat	9.8	10.5	7%
Peas	1.1	1.5	15%
Onions	0.7	0.8	12%
Carrots	1.2	1.6	25%
Potatoes	3.2	3.75	14%
Overall	16.0	17.95	11%

Although the meat did not meet the minimum level required for it, the other components added enough cushioning effect to reduce breaking up of the meat. The onions being such a small part of the overall stew, created no problems at any time.

Spraying the stew to lower levels than 10% was insufficient to meet the minimum levels, especially for the potatoes, and higher I_f was obtained. Lower equilibration times also lessened the reductions in fragmentation.

Upon studying the two tables above, the moisture content of the carrots, onions and peas could be reduced substantially without increasing fragmentation.

The only possible method, however, of obtaining optimum moisture levels for each component is to spray each one separately. This method was successful in reducing fragmentation even further (I_f of 1.2) and also increasing rehydration properties. Although the overall moisture could be reduced, the advantages gained by this method did not warrant the use of this complicated procedure over the 10% spray treatment.

The preferred method used for preparing beef stew for storage stability tests is as follows:

1. Spray formula proportions of the beef, carrots, potatoes, peas, and onions together with sufficient water to raise moisture level of the mixture by 10%.

2. Allow to equilibrate for one hour in a closed container.

3. Mix in the gravy and spice mix and compress immediately.

4. Redry the beef stew bars in a vacuum oven for 5 hours at 60°C.

B. PRODUCT STABILITY

Storage stability tests were made on beef stew bars after 2½ months storage and are tabulated in Table XX. The flavor of the meat was seriously affected by the storage at 70° and 100°F. There did not appear to be any change in flavor of the vegetables during storage.

TABLE XIX

STORAGE STABILITY EVALUATION OF BEEF STEW - 2.5 MONTHS

Code & Treatment	Storage Condition	It	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating
BS-C	Initial	-	5.9	-	2.4	0.18	-	5	T	T	T	T	5
No	Cycling	-	5.9	-	-	-	-	8	T	T	T	T	5
Treatment	70°F	-	-	-	-	-	-	8	Very Sl. Rancid	T	T	T	4
Non-Compressed	100°F	-	6.1	-	-	-	-	8	Burnt In Flavor	T	T	T	3
BS-CP	Initial	5.0	6.2	0	2.4	-	-	4	T	T	Mush	T	0
No	Cycling	-	6.0	0	2.2	-	-	4	T	T	"	T	0
Treatment	70°F	-	6.1	0	3.2	-	-	4	Sl. Rancid	T	"	T	0
Compressed	100°F	-	6.05	0	2.9	-	-	4	Burnt	T	"	T	0
BS-10W	Initial	1.6	6.1	3	2.4	0.83	Acceptable	6	T	T	T	T	4
10% Water	Cycling	-	5.9	3	1.0	0.83	"	8	T	T	T	T	4
Compressed	70°F	-	6.1	3	1.0	0.84	"	8	Very Sl. Rancid	[illegible]	T	T	4
	100°F	-	6.0	3	1.9	0.82	"	8	Burnt	T	T	T	3

Notes: T = Typical.

The flavor of the beef stew was most seriously affected by storage. The vegetables did not appear changed after storage.

Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

X. RAW BEEF

The raw beef used in this project was purchased, cut and cubed according to Military Specifications LP/P, DES C-204-60. U. S. Standard grade or better was used, cut into pieces approximately ½" thick perpendicular to the fibers, and approximately 1" x 1" parallel to the fibers. The beef was then freeze dried in a RePP Freeze Dryer to a final moisture of less than 2.5% (fat-free basis).

A. REDUCTION OF FRAGMENTATION

Freeze dried raw beef, compressed without any treatment, fragmented severely. The meat was completely broken up into small pieces and fines. ($I_f = 7.0$).

1. Water Spray

Fragmentation of freeze dried beef can be greatly reduced by treating the beef with water. Using methods similar to those for other foods mentioned in this report, water was sprayed on at various levels (5-12%) to achieve optimum reduction of fragmentation, cohesion and rehydration characteristics. In the case of beef, however, the minimum level of water (8%) needed to substantially reduce fragmentation was too high to permit rehydration of the compressed bar within a reasonable time. At an 8-12% water level, the meat surface was sticky causing excessive cohesion and subsequent poor rehydration. Of the ingredients tried (i.e., starches, gums and surfactants) a modified tapioca starch (Crystal Gum, National Starch Co.) added to the water sprayed on was found most successful in reducing the rehydration time of beef sprayed at 8-12% water level. However, the Crystal Gum imparted a slight off flavor to the beef and was considered unacceptable for this reason.

2. Humidification

A new method of introducing moisture was then developed for the raw beef which involved equilibration in a high humidity chamber to an added moisture level of 8%. This method yielded bars with less fragmentation ($I_f = 1.3$) than a comparable water level using the water spray ($I_f = 3.1$). Rehydration occurred within 25 minutes (25 minutes rehydration is also required for non-compressed raw beef) and the bar had fair cohesion.

The freeze dried meat was subjected to high humidity (approximately 88%) in a sealed chamber with good surface-to-air contact for a period of about 25 minutes. The added moisture level was about 8%. The moist air was circulated by a fan to increase rate of moisture pick up. This procedure eliminated wet spots on the surface of the meat which had previously caused the excessive adhesive effect. The beef was compressed to 1100 psi with the fibers oriented parallel to the direction of compression. It was found that compression of meat oriented perpendicular to the line of compression had comparatively poor rehydration characteristics. After compression, the bar was redried to a moisture of less than 2% in a vacuum oven at 40°C for 8 hours. Treating the meat in this manner gave the best overall results of all treatments investigated and was used in preparing samples for storage stability.

3. Other Treatments

A number of approaches were tried during the course of this project in an effort to: a. reduce fragmentation due to compression; b. increase the rate of penetration of water into the meat pieces; or c. increase the rate of separation of individual meat pieces during rehydration so that all possible surfaces would be exposed. Among those treatments which were considered to contribute little or nothing to the purposes of this project may be listed the following:

- Spraying and equilibration with propylene glycol before compression.
- Rehydration with solutions of surfactants.
- Dusting surface of meat pieces with starch before compression.
- Spraying with emulsions of oil, water and emulsifier before compression.
- Dipping meat pieces in beef tallow.
- Spraying with ethanol.

Equilibrating and compressing at temperatures from ambient to 60°C.

- Incorporation of gum (arabic) into water spray used to soften meat pieces.

Treatments were considered ineffective if bars did not separate into component pieces or if pieces did not rehydrate completely within a reasonable (one hour) time in room temperature water. No measurements of Index of Fragmentation were considered valid unless performed on fully rehydrated product.

B. PRODUCT STABILITY

Samples of freeze dried raw beef bars prepared by the humidification method (X., A., 2., above) were placed in storage with untreated, non-compressed controls and with untreated, compressed controls. (Table XX). The flavor of both the treated bars and the controls were considered poor after six months at all prescribed storage conditions.

XI. SPINACH

The materials used for this study was commercial frozen spinach, cooked, refrozen and freeze dried by Tronchemics Research, Inc.

A. INDEX OF FRAGMENTATION

In considering a method to be used for determining an "Index of Fragmentation" for spinach, it was anticipated that the two-dimensional nature of spinach might make this product unsuitable for application of the screen analysis method developed and used for all other products studied during the course of this project. It was believed that large spinach leaves might tend to "blind" the openings of the larger sieve sizes used in the method for determining Index of Fragmentation described earlier in this report. If such "blinding" occurred, it was expected to be difficult or impossible to achieve a satisfactory separation of fragmented spinach particles from larger pieces.

However, the Standard Wet Screen Analysis procedure was found to perform well in measuring the degree of fragmentation due to compression. This method, therefore, provides the basis for results recorded in Table XXI.

Another method to measure the fragmentation of spinach due to compression is based on the water holding capacity of various sizes of leaves or leave pieces. Data (Progress Report No. 6) showed that the higher the degree of fragmentation, the lower the total weight of the rehydrated tissue and vice versa. In later studies, this method was found to be as reproducible as the Standard Wet Screen Analysis procedure. However, the Wet Screen Analysis procedure was selected for evaluations performed during this contract in order to provide uniformity of results and identity of the definition of the term "Index of Fragmentation".

TABLE XX

STORAGE STABILITY EVALUATION OF RAW BEEF - 6 MONTHS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating
RBC	Initial	1	5.6	-	2.2	.17	NOT APPLICABLE	25	T	T	T	Dark	3
No	Cycling		5.4	-	-	-		"	Low	Low	Tough	"	2
Treatment	70°F		5.5	-	-	-		"	Poor,	Poor	Tough	"	3
Non-Compressed	100°F		5.5	-	-	-		"	Sl.Burnt	Sl.Burnt	Tough	"	2
RBCP	Initial	7	5.5	0	2.2	.60		"	T		Frag.	"	2
No	Cycling		5.6	1	1.8	.70		"	Low		Soft	"	2
Treatment	70°F		5.5	1	1.9	.75		"	Poor,Sour	Sour	Soft	"	2
Compressed	100°F		5.4	1	1.8	.77		"	Poor,Sour	Sour	Soft	"	2
RBSW	Initial	1.4	5.5	2	1.8	.60		"	T		T	"	3
8% Water	Cycling	1.7	5.5	2	1.7	.70		"	Low		Tender	"	2
Compressed	70°F	1.8	5.5	6	1.7	.65		"	Poor,	Sl.Burnt	Tender	"	3
	100°F	1.6	5.6	3	1.5	.65		"	Sl.Burnt	Sl.Burnt	Tender	"	2

Note: T = Typical.

Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

B. REDUCTION OF FRAGMENTATION

Freeze dried spinach is extremely fragile and is fragmented severely (I_f = 6.8) by compression. Upon rehydration of the compressed material, the appearance is that of a coarse puree, with many small pieces visible.

1. Water Treatment

A cohesive, rapidly rehydrating spinach bar, with little or no fragmentation, was made by spraying freeze dried spinach with 10% water (optimum) and equilibrating in a closed container for 30 minutes prior to compression. After compression, the water is removed in a vacuum oven at 45-50°C for at least 6 hours. Moisture content of the dried bars ranges between 1.3-1.8%. The density of the freeze dried spinach increases from 0.18 to about 0.67 g/cc. due to compression. The rehydration time of these bars is about 15 minutes in warm water and only 2-4 minutes in water poured from a container of boiling water.

During rehydration, the individual leaves and large sections of spinach leaf can be seen to unfold as the bar expands to several times its original volume. Little or no agitation is required. The appearance is essentially identical to that of the uncompressed control.

This method is the preferred procedure by which bars were prepared for storage.

2. Glycerin Treatment

Glycerin treatment alone did not reduce the fragmentation due to compression of spinach significantly. Spraying a 1:1 ratio of glycerin and water did reduce the fragmentation effectively. This reduction appears to be due mainly to the water part of the treatment. Results are reported in Table XXI.

C. STORAGE STABILITY OF SPINACH

Table XXII summarizes the stability evaluations of spinach bars at zero time and after six months storage. Results after six months storage show an insignificant decrease of pH of all samples stored at 100°F. Off flavor had developed in samples stored at 70°F and 100°F. Samples stored at 100°F also lost some of their color intensity. These undesirable changes appeared in all samples, whether treated or untreated, compressed or not compressed. Despite these undesirable changes in the flavor and color of samples stored six months at 70°F and 100°F, they were still considered acceptable by the evaluating panel.

TABLE XXI

THE EFFECT OF WATER AND GLYCERIN TREATMENTS ON THE I_f AND RATE OF REHYDRATION OF SPINACH BARS

5 g. Samples	Treatments	I_f	(Time of Rehydration) Water at Room Temp.	Boiling Water
11-46-1	Control, No Compression	1	5	2-3
11-46-2	0% H_2O, Compressed	7.3	10	2-3
11-52-2	5% H_2O, Compressed	1.7	5	2-4
11-52-3	7.5% H_2O, Compressed	1.7	5	2-4
11-52-4	10% H_2O, Compressed	1.0	15	2-4
11-52-5	15% H_2O, Compressed	1.0	30	2-4
11-50-3	10% Glycerin, Compressed	5.4	15	2-3
11-50-2	10% 1:1 Glycerin-Water, Compressed	1.4	10	2-3

TABLE XXII

STORAGE STABILITY EVALUATION OF SPINACH - 6 MONTHS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density g/cc	Chewability (Dry)	Rehy. Time (Min)	Flavor	Aroma	Texture	Color	Overall Rating
Control, Not Treated, Not Compressed	Initial	1.0	6.9	-	1.5	0.08	Good	1-2	T	T	T	T	5
	Cycling	-	6.85	-	2.3	-	"	"	"	"	"	"	4-5
	70°F	-	6.95	-	2.0	-	"	"	Rancid Off	Rancid Off	"	"	3
	100°F	1.8	6.72	-	2.0	-	"	"	"	"	"	Lt. Green	3
Not Treated, Compressed	Initial	7.9	6.88	10+	1.6	0.57	Powdery	2-3	T	T	Mushy	T	1
	Cycling	14.4	6.95	10+	2.0	0.47	"	"	"	"	"	"	1
	70°F	15.6	6.82	10+	2.0	0.49	"	"	Hay-Like Tea-Like Rancid	Hay-Like Tea-Like Rancid	"	"	0
	100°F	15.3	6.56	10+	2.0	0.47	"	"	"	"	"	Lt. Green	0
Treated, (10% H_2O), Compressed	Initial	1.03	6.92	10+	1.5	0.69	Good (Harder)	3-5	T	T	T	T	4-5
	Cycling	1.2	6.70	10+	2.0	0.65	" "	"	"	"	"	"	4-5
	70°F	1.1	6.85	10+	2.0	0.70	" "	"	Burned Off Flavor, Rancid	Burned Off Flavor, Rancid	"	"	3
	100°F	1.2	6.72	10+	2.0	0.63	" "	"	"	"	"	Lt. Green	3

Note: T = Typical.

Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

XII. CHILI CON CARNE

Ingredients of dry chili con carne (59% beans, 25% ground beef and 16% seasoning mix) used in this study were prepared according to Military Specification LP/P DES C-186-62. The seasoning mix was prepared from tomato powder (41.2%) dried soup and gravy base, beef (25.1%), chili powder seasoning (18.9%), salt (14.7% and garlic powder (0.2%).

A. REDUCTION OF FRAGMENTATION

Compression of chili con carne resulted in considerable fragmentation of both the freeze dried beef and bean components ($I_f = 3.6$). The appearance of the rehydrated product was unattractive due to the lack of typical whole beans in the mixture.

Water treatment of the complete formulation by the spray technique, found successful in other products, was evaluated. After equilibration, it was found that most of the water spray had been absorbed by the seasoning mix and fragmentation of beans and meat upon compression was still severe. No means was found for spraying water on the complete chili con carne mix to accomplish substantial reduction of fragmentation without encountering other problems due to excessively wet seasoning mix, etc.

Further studies were directed toward separate water treatments of the beans and beef.

It was found that a water spray treatment (20-30%) of beans followed by an equilibration time of 2 hours prior to compression was the most effective treatment to reduce fragmentation of the beans due to compression.

Spraying beef with 10% water followed by a 30 minute equilibration time was found to be effective in reducing the fragmentation of the beef due to compression. Other approaches to reduce fragmentation due to compression of both beans and beef, including the spraying with glycerin, propylene glycol and applying heat, were not effective in reducing fragmentation.

It was found that spraying the beef, equilibrating the beef and beans each according to the optimum conditions, followed by combining with dry seasoning mix and compressing was the most effective method of reducing fragmentation. The procedure adopted is described in the following.

1. Water Treatment of Chili Con Carne

The bean component of the chili con carne formulation was sprayed with water to a moisture increase of 20% and the sprayed product was placed in a closed container to equilibrate for 1.5 hours. The beef component was sprayed with 10% water and added to the beans at the end of the 1.5 hour equilibration time. The combination of beans and beef was further equilibrated for an additional 30 minutes.

The formula quantity of dry seasoning mix was then added to the equilibrated beef and beans, mixed thoroughly and bars were compressed at 1100 psi. After compression, the bars were dried in the vacuum oven at 50°C overnight.

The above technique was used for all bars prepared for storage evaluation as reported in Table XXIII.

B. STABILITY OF CHILI CON CARNE

Initial and four months storage evaluations indicate that treated chili bars are considered to be stable and received a high overall rating score when compared with the control. Bars stored at 100°F seemed to have lost some of their flavor characteristics. Other evaluations of various treatments after four months storage were unchanged compared to the initial results. (Table XXIII).

[illegible]

STORAGE STABILITY EVALUATION OF CHILI CON CARNE AFTER 4 MONTHS

Code & Treatment	Storage Condition	I_f	pH	Drop Test	Moisture %	Density g/cc	Chewability (Dry)	Rehy. Time (Min.)	Flavor	Aroma	Texture	Color	Overall Rating
Control,	Initial	1	5.5	-	1.8	0.32	dry	7-10	T	T	T	T	5
Not Compressed,	Cycling	-	-	-	-	-	-	-	-	-	-	-	-
Not Treated	70°F	-	-	-	-	-	-	-	-	-	-	-	-
	100°F	-	-	-	-	-	-	-	-	-	-	-	-
Control,	Initial	3.65	5.4	0	2.0	-	-	3-4	T	T	Soft	T	1
Not Treated, Compressed	Cycling	2.8	5.75	0	1.4	-	-	3	Low Flavor Level	Weak Spice	Soft, Powdery	T	1
	70°F	3.2	5.8	0	1.1	-	-	3	"	"	"	T	1
	100°F	3.1	5.8	0	-	-	-	3	"	"	"	T	1
Treated,	Initial	1.9	5.5	10	1.9	0.89	dry-hard	7-12	T	T	T	T	4
20% H_2O for Beans	Cycling	1.85	5.9	1	1.1	0.84	" "	6	T	T	T	T	4
10% " " Beef	70°F	1.95	5.5	5	1.2	0.82	" "	6	T	T	T	T	4
0% " for Seasoning	100°F	1.98	5.7	4	1.1	0.81	" "	8	Good But Sl. Weaker	T	T	T	3-4

Note: T = Typical.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

XIII. MUSHROOMS (Agaricus campestris)

Materials used in this study were 1.) freeze dried diced mushrooms prepared by United Fruit & Food Corporation (pH 6.5, moisture 1.3%); and 2.) cooked freeze dried diced mushrooms prepared by Tronchemics Research Incorporated (pH 6.6, moisture 1.5-2%).

A. REDUCTION OF FRAGMENTATION

The compression of freeze dried mushrooms results in considerable fragmentation. (I_f = 14.0). The compression of the raw mushrooms obtained from United Fruit increased rehydration time from 3 minutes to more than 2.5 hours. On the other hand, the compression of the cooked mushrooms prepared by Tronchemics Research increased rehydration time from 3 minutes to less than 25 minutes. The Statement of Work of this project does not specify cooked mushrooms, therefore the cooking process described later is regarded as an important step in the process developed to prepare compressed mushroom bars with substantially no fragmentation (I_f = 1.4). The Index of Fragmentation of raw mushrooms could also be reduced to about 1.4, (see Table XXIV), but rehydration was so long that the product was judged to be virtually inedible.

1. Water Treatment of Cooked Mushrooms

Cohesive, relatively rapidly rehydrating bars with little fragmentation have been successfully developed. These bars were made as follows: Fresh mushrooms were diced (½" x ½" x ½"). Dices were placed in a 2% NaCl solution to retard enzymatic and oxidative browning. After accumulating enough sample, the dices were transferred into a pan with boiling water and cooked for 40 minutes. The material was then cooled to room temperature, frozen and freeze dried. The freeze dried mushrooms were uniformly sprayed with 5-7% distilled water and equilibrated in a sealed container for 25 minutes prior to compression at 1100 psi. Compressed bars were then dried in a vacuum oven overnight at 50°C. This treatment reduced the Index of Fragmentation from 14.0 ± 3.0 for the control to 1.4 ± 0.3 for the treated sample. The rehydration time was also reduced from more than 2.5 hours for the control to less than 25 minutes for the treated sample (Table XXIV). This method was not developed early enough to be used for storage studies.

TABLE XXIV

EVALUATION OF FREEZE-DRIED MUSHROOM

Treatments	I_f	pH	Drop Test	Moisture (%)	Density	Chewability (Dry)	Rehy. Time	Flavor	Aroma	Texture	Color	Overall Rating
Raw, Not Treated, Not Compressed	1	6.52	-	1.2	0.06	Good	2-4 min.	T	T	T	T	5
Raw, Not Treated, Compressed	14 ± 3	5.54	10+	1.3	0.54	Powdery	>2.5 hrs.	Fair	Fair	Mushy	Brown	1
Raw, Treated 8% H_2O, Compressed	1.4 ± .4	6.58	10+	1.3	0.52	Hard	>2.5 hrs.	Fair	Fair	Fair	Brown	3.5
Cooked, Not Treated, Not Compressed	1	6.60	-	1.5	0.06	Good	2-4 min.	T	T	T	T	5
Cooked, Not Treated, Compressed	-	-	10+	-	0.48	Powdery	25 min.	T	Mushy	Mushy	T	1
Cooked, Treated (5-7% H_2O), Compressed	1.4 ± .3	6.65	10+	1.4	0.55	Hard	25 min.	T	Mushy	T	T	4.5

Note: T = Typical.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.

2. Water Treatment of Uncooked Mushrooms

Freeze dried diced mushrooms from United Fruit & Food Corporation were used in this method. Five to ten per cent distilled water was sprayed evenly on the mushrooms and equilibrated in a sealed container for 30 minutes prior to compression. The compressed bars were then dried in a vacuum oven overnight at 50°C. This treatment reduced the Index of Fragmentation from 14.0 ± 3 for the untreated compressed samples to 1.4 ± 0.4 for the treated compressed ones. But the rehydration time was increased from about 3 minutes for the untreated not compressed control to more than 2.5 hours for the treated compressed samples. (Table XXIV).

Bars prepared by this treatment were evaluated initially and after storage for 6 months. The evaluations of the stored bars are not reported here since neither the fresh nor the stored bars were considered suitable for food use due to excessive darkening which occurred during the long rehydration time. However, little change in the character of the bars seemed to have occurred during storage.

3. Other Treatments

Prior to reaching the most effective treatment to reduce both the fragmentation and rehydration time of a compressed mushroom bar, many unsuccessful attempts were conducted primarily to reduce the time of rehydration, such as:

a. Spraying a 10% suspension of Crystal Gum Starch (modified tapioca, a product of National Starch & Chemical Corporation) prior to compression.

b. Surface drying of water sprayed mushrooms in a forced air oven prior to compression.

c. Lamination of the compressed layers held together by further compression.

d. Rehydration in hot water.

e. Infiltrating the raw diced mushrooms prior to freeze drying with:

(1) 1% $CaCl_2$ solution.

(2) 1% low methoxy (25-28%) pectin (type pink, a product

of Colyer Company, Inc.).

(3) 20% sugar solution.

(4) Enzyme system made of 0.5% of each pectinase, hemicellulase, dextrinase, bromilain (a proteolytic enzyme) and Dee-O (enzyme, glucose - gluconic acid).

XIV. SCRAMBLED EGGS

Cooked freeze dried scrambled eggs prepared according to Military Specification LP/P DES C-203-63 were used in this investigation. The procedure described in this specification was modified with respect to the cooking operation to prepare partially cooked and uncooked scrambled eggs as described below.

A. INDEX OF FRAGMENTATION

Attempts to use the standard method of determining the Index of Fragmentation (I_f) were not successful. Spraying the scrambled eggs during the screening operation broke up the fragile scrambled egg curds resulting in an erroneously high I_f. Another technique was developed which replaces spraying with a dipping operation. This method is described as follows:

U. S. Standard sieves #5/16, 5, 10, 16 and 200 are used. The complete set of sieves is stacked in the usual manner wherein the sieve of the smallest opening (#200) is placed on the bottom. A harness consisting of three wires (1/8" in diameter) is arranged with the wires at about equal distances radially from each other to support the stack so that all sieves are kept adequately together during handling. The sieve stack is placed in a vessel with enough water to cover all but about 1/3 of the top sieve. The projecting top of this sieve prevents loss of product during a subsequent dipping operation.

The scrambled egg sample is placed in the top sieve. The set of sieves is gently lifted one inch out of the water and dipped again twice. The purpose of the lifting and dipping operation is to segregate the various scrambled egg particles into five sizes represented by the five sieves. This operation provides a more gentle action than the spraying procedure used in the screen analysis method developed in this contract for measuring the Index of Fragmentation.

Two dips were found to be sufficient to segregate and collect the different particles sizes in the respective sieves. In the case of highly fragmented samples, however, one dipping was found to be enough since most of the material is collected on the sieve of the smallest openings (#200) immediately after pouring the sample on the top sieve while the stack is immersed in the water. Draining the water by lifting up the sieves was obrerved to be slow in the case of highly fragmented samples because the small particles tend to seal the tiny openings of sieve #200. The stack must be lifted from the water gently at the end of the operation to prevent forcing fine particles through the smaller sieve openings.

The segregated portions on each sieve are collected, filtered and weighed as in the standard procedure for determining I_f. Table XXV shows that 89.9% of the total wet weight of the control (cooked, untreated, uncompressed) samples and 88.2% of the treated (partially cooked and compressed with heated dies) samples was collected on the largest opening sieve. Only 1.2% and 1.6% of the total wet weight respectively was collected on the smallest opening sieve (#200). On the other hand, none of the untreated compressed sample was collected on sieve #5/16, while 83.3% of the total wet weight was collected on the 200 mesh sieve.

The method discussed above has been adopted as the procedure to be used for measuring the I_f of scrambled eggs.

TABLE XXV - WET WEIGHT OF SCRAMBLED EGGS

(Results are Averages of Duplicates)

13 g. Sample	Treatment	Total Wet Wt.	% of Wet Weight On Sieve #5/16	On Sieve #200
11-114-7	Control (cooked, not treated, not compressed).	46.1	89.9	1.2
11-114-8	Cooked, not treated, compressed.	25.7	0	83.3
11-114-5	Treated (partially cooked, compressed heated die)	50.6	88.2	1.6

B. REDUCTION OF FRAGMENTATION

The compression of untreated freeze dried scrambled eggs caused excessive fragmentation of the curds and prevented the scrambled eggs from rehydrating. Treating the bars with a plasticizer to reduce the fragmentation further aggravated the rehydration problem. A unique technique for scrambled eggs was developed which resulted in bars that rehydrated into a typical curd structure within 3 minutes. This technique depends upon using partially cooked scrambled eggs in the bar. Upon rehydration with boiling water, these further coagulate to form the curd structure expected in scrambled eggs.

1. Partial Cooking Treatment

A partial cooking of scrambled eggs prior to freeze drying was found to provide the best means of producing a compressed bar which would rehydrate with typical scrambled egg characteristics.

A typical preparative procedure for partially cooked scrambled eggs is as follows:

5016.8 gm. raw, scrambled egg mixture (75% eggs, 24.16% water and 0.39% salt) was poured into a six gallon capacity kettle. This was placed in a boiling water bath and the eggs were cooked with continuous stirring. Cooking was stopped when the eggs were judged (subjectively) to be 50% coagulated. The operation required 13½ minutes and the highest temperature of the scrambled eggs reached at the end of this period was 77°C. The product was spread to one half inch thickness on trays, cooled, frozen at -12°F and freeze dried.

Partially cooked freeze dried scrambled egg samples were compressed in a die heated to 60°C and a compression plate temperature of 60°C. The die was reheated after every three compressions to maintain a relatively uniform temperature during compression operations. A dwell time of 45 seconds in the heated die seems to form a thin, smooth outer surface which is relatively resistant to breakage during ordinary handling. This layer is probably due to surface coagulation of the partially cooked scrambled eggs used for these experiments. Heating the freeze dried egg prior to compression results in an undesirable granular texture after rehydration which is probably due to complete coagulation of the partially cooked scrambled eggs.

Compressed bars should be broken down with the fingers into powder before the addition of water. This is especially true for the control (fully cooked) compressed eggs and the partially cooked, heated, then compressed bars. The curd size of the reconstituted scrambled eggs of the treated samples depends largely on the degree of stirring during rehydration. More stirring tends to decrease the sizes of curds and vice versa. These curds are usually more fluffy than the rehydrated control uncompressed samples.

Typical rehydrated freeze dried fully cooked scrambled eggs exhibit a spongy and watery mouthfeel. On the other hand, the treated (partially cooked, compressed) samples developed a more desirable mouthfeel typical of fresh scrambled eggs after rehydration.

2. Other Treatments

Spraying the freeze dried egg with water, glycerin, fat, starch and gum solutions prior to compression, using dried egg white, uncooked and partially cooked portions as coagulants, and heat applications on the product prior to compression yielded bars which either would not rehydrate within a practical time limit or which fragmented excessively.

C. STORAGE STABILITY OF SCRAMBLED EGGS

Table XXVI summarizes the I_c and various tests of stability of scrambled eggs initially and after 4½ months storage. Final results show that scrambled eggs of the treated (partially cooked) sample are as good as, if not better, than the control (fully cooked, not compressed).

TABLE XXVI

STORAGE STABILITY EVALUATION OF SCRAMBLED EGGS - 4.5 MONTHS

Code & Treatment	Storage Condition	If	pH	Drop Test	Moisture%	Density	Chewability (Dry)	Rehy. Time (Boiling H_2O)	Flavor	Aroma	Texture	Color	Overall Rating	Remarks
Control,	Initial	1	8.20	-	1.5	0.375	Good	1-3 min.	T	T	T	T	5	-
Not Treated,	Cycling	-	-	-	-	-	-	-	-	-	-	-	-	-
Not Compressed	70°F	-	-	-	-	-	-	-	-	-	-	-	-	-
	100°F	-	-	-	-	-	-	-	-	-	-	-	-	-
Not Treated,	Initial	14.8	8.35	1	1.3	0.90	Hard	3*	T	T	Granular	T	2	-
Compressed	Cycling	14.6	8.5	1	-	0.90	Dry, Granular	3*	T	T	"	T	2	-
	70°F	14.7	8.5	0	-	-	" "	3*	Mild Burnt	Old Egg	"	T	2	-
	100°F	14.7	8.1	0	-	-	UA	3*	Burnt, Bad Egg	Burnt Egg	"	Brn.	1	UA
Treated, Partially	Initial	1	8.25	2	1.3	0.90	Tender, Not Crumbly	2-4 min.	T	T	T	T	4-5	-
Cooked, Heated	Cycling	1	8.7	2	1.2	0.91	" " "	3	T	T	T	T	4	-
Die, Heated	70°F	1	8.45	2	0.8	0.96	" " "	3	Mild Burn	Old Egg	T	T	3	-
Plates, Compressed	100°F	1	8.1	2	1.2	0.87	UA	3	Burnt, Bad Egg	Lt. Burnt Egg	Mushy	Lt. Brn.	1	UA

Notes: T = Typical.
UA = Unacceptable.
Overall Rating: 1 = Very Poor; 2 = Poor; 3 = Fair; 4 = Good; 5 = Excellent.
* = Most of the egg was rehydrated; however, several small, hard, unrehydrated granules remained. To soften these granules would require an excessively long time.

XV. STRAWBERRIES

Materials used for this investigation were freeze dried strawberries prepared by Tronchemics Research, Inc.

A. REDUCTION OF FRAGMENTATION

Efforts to reduce fragmentation of compressed strawberries have not been successful because of our inability to produce bars which can be rehydrated in a reasonable period of time. It has been possible, however, to separate the individual compressed berries after about one hour rehydration time.

The best treatment was as follows:

Fresh strawberries were punctured with stiff wires spread in a frame approximately 5 mm. apart and vacuum infiltrated with 1% low methoxy (25-28%) pectin (a product of Colyer Company) solution (3 times, 10 minutes, each) in vacuum oven. The strawberries were further infiltrated (same procedure as for pectin) with 1% $CaCl_2$ solution. The material was then freeze dried. A dry "calcium pectate" was prepared by precipitating a 1% solution of the low methoxy with an equivalent amount of 1% $CaCl_2$ solution. The supernatant liquor was drained and the gel was frozen and freeze dried.

One part of this calcium pectate was dusted on 20 parts by weight of infiltrated strawberries in an effort to promote absorption of water throughout the compressed bar. The freeze dried strawberries and freeze dried calcium pectate were mixed. The sample was compressed at 500 psi and formed a cohesive, slowly rehydrating bar. Bars prepared by this treatment were partially rehydrated in less than one hour compared to the control which rehydrated in more than 8 hours. This partial rehydration of the treated bars took the form of separation of the individual berries although water did not necessarily penetrate through all of the individual flat berries. The rehydrated strawberries were considered acceptable by the panel, however.

The I_f values of the treated samples (measured by using the wet screen analysis) range between 1.3 to 3.4. Since it has not been possible to rehydrate the control (untreated) compressed bars to establish I_f values, it was not possible to determine the degree of reduction of fragmentation of treated samples in comparison with compressed controls.

However, it is important to indicate in this connection, that a relatively light pressure applied to freeze dried berries results in a powder and a consequent high I_f value. When higher pressure is applied to freeze dried strawberries, a cementing effect occurs forming hard bars virtually impossible to rehydrate.

The following approaches were attempted and were considered unsuccessful.

1. Treatment of freeze-dried strawberries with water prior to compression.

2. Treatments with starches either sprayed on as suspensions using 10% of Crystal Gum (a modified tapioca starch) or powdered using 5% Dry Flo (a modified corn starch). Both are products of National Starch & Chemical Corporation.

3. Treatment by surface drying of freeze dried strawberries after spraying with either water or Crystal Gum starch suspension prior to compression.

4. Treatments by vacuum infiltration of fresh strawberries with 1% solutions of Ca acetate, Ca lactate, or Ca chloride.

5. Lamination of thin compressed strawberry chips held together by further compression.

6. Puncturing holes with a fork prior to compression.

7. Combinations of some of the above.

8.* Infiltration of fresh strawberries with enzymatic systems of Dee-O (glucose oxidase), hemicellulases, pectinases, bromelain (proteolytic) dextrinase and HT-2000 (amylase-protease) separately and in combination, then freeze dried.

9. Infiltration of fresh strawberries with 1% low methoxy pectin solution with or without subsequent infiltration with 1% $CaCl_2$ solution.

10. Infiltration of fresh strawberries with 5% of Melogel starch (a corn starch from National Starch Co.) suspension with and without heat application.

*Enzymes used were obtained from Miles Chemical Company.

XVI. COTTAGE CHEESE

The cottage cheese used for these studies was the commercial product purchased in local stores.

Ordinary freezing of cottage cheese in a deep freezer followed by freeze drying produced a dry product that was matted to the point that the individual curds could not be distinguished or separated. Evaporative freezing in the freeze dryer prior to the freeze drying step was the only method found to produce an acceptable product from which the curds could be separated by hand to meet the requirements in military specifications LP/P DES C-197-62. Upon compression of this dry product without treatment, a very cohesive bar with no visual evidence of curds was produced. This bar would not rehydrate even after standing in water overnight. Breaking up the bar with a fork did not help to promote rehydration as the final product still contained unrehydrated lumps. The rehydrated portion had little resemblance to the original product.

A variety of treatments, including most of the ones that had proved successful on previous products, were tried to promote rehydration. These treatments included water sprayed at various levels, varying equilibration times, use of distilled monoglycerides (1-5% dispersions sprayed on) and low viscosity starches (5-20% dispersions sprayed on), compression at elevated temperatures (60°C) and cooling to 0°C before compression.

Since no direct treatment of freeze dried cottage cheese was found to be effective in yielding a typical curdy product after rehydration of compressed bars, no storage tests were possible for this product.

It is believed that follow up work for this project might investigate an approach patterned after the procedure found to be effective for scrambled eggs as described earlier in this report. This procedure which may yield bars which would rehydrate to a typical curdy cottage cheese structure is suggested to be the following:

It is proposed to make a cottage cheese preparation and freeze dry the mixture before coagulation is complete, with the intention of allowing coagulation to be completed upon subsequent rehydration of compressed bar. Sterilized raw milk would be innoculated with a "mother culture", forming a starter culture for cottage cheese. The starter would then be innoculated into the skim milk and rennin added to speed up the coagulation action.

This mixture would then be immediately frozen to limit coagulation or might be allowed to partially coagulate before freezing. The product would be freeze dried and the resulting partially coagulated or uncoagulated dried powder would be compressed into bars. It is believed that these bars could be broken up into powder or pieces by hand and rehydrated at room temperature or slightly above, allowing time for the normal coagulating effect to occur.

The above procedure has not been evaluated in the laboratory because of lack of project time. It is proposed here only as a possible approach to solving what appears to be a very difficult problem of making rehydratable compressed bars of cottage cheese.

. HUMIDITY-MOISTURE EQUILIBRIUM

The Statement of Work for this project specifies that the contractor will describe the effect of recommended procedures for reduction of fragmentation on the equilibrium relative humidity of specified bars at 20°C.

The results from the humidity-moisture equilibrium measurements of products specified in the Statement of Work are given in Figures I-VII. The measurements were made on the uncompressed, non-treated product (control) and the corresponding treated compressed bar.

These results indicate that treating the bars to reduce fragmentation does not affect the humidity-moisture equilibria at 20°C. Strawberries were not tested because a satisfactory way of making an acceptable bar was found only at the end of the contract period.

PRELIMINARY COMMERCIAL FLOW DIAGRAM AND EQUIPMENT SELECTION

A. PRELIMINARY BAR PRODUCTION FLOW DIAGRAM

As a guide for future efforts to translate the developmental results described in this report into a commercial production facility for compressed food bars, a preliminary flow diagram was prepared (see Figure VIII). Several representative products are listed on this diagram. Similar diagrams could be used for the products not specifcally listed here.

For reference purposes, Table XXVII lists the processing steps involved in the production of compressed bars from all foods included in the contract with the exception of cottage cheese and strawberries.

TABLE XXVII

PROCESSING STEPS AND CONDITIONS IN FRAGMENTATION CONTROL FOR COMPRESSED FOODS

Product	Addition	Surface Drying	Equilibration	Addition	Equilibration	Comp. at 1100 psi	Drying
Shrimp	5% PG Spray	-	60°C 1 Hr.	-	-	60°C	-
Ground Beef	10% PG Spray	-	60°C 1 Hr.	-	-	60°C	-
Rice	10% H_2O w. 10% GA Spray	R.T. 5 min. Fan-Mix	-	-	-	R.T.	70°C, 28" Vac. 5 Hrs.
Onions	4% Oil Spray	-	R.T. 1 Hr.	9% H_2O Spray	R.T. 3 Hrs.	R.T.	50°C, 28" Vac. 12 Hrs.
Peaches	-	-	-	-	-	R.T.	-
Peas	5% H_2O Spray	-	R.T. 5 min.	-	-	R.T.	-
Corn	5% PG Spray	-	60°C 1 Hr.	-	-	60°C	-
Beef Stew	5-15% H_2O Spray*	-	R.T. 1 Hr.	-	-	R.T.	45°C 28" Vac. 12 Hrs.

TABLE XXVII (CONT'D)

PROCESSING STEPS AND CONDITIONS IN FRAGMENTATION CONTROL FOR COMPRESSED FOODS

Product	Addition	Surface Drying	Equili-bration	Addition	Equili-bration	Comp. at 100 psi	Drying
Raw Beef	7% H_2O Humidity Chamber	-	-	-	-	R.T.	45°C 28" Vac. 12 Hrs.
Mushrooms	10% H_2O Spray	-	R.T. ½ Hr.	-	-	R.T.	45°C 28" Vac. 12 Hrs.
Spinach	8% H_2O Spray	-	R.T. ½ Hr.	-	-	R.T.	45°C 28" Vac. 12 Hrs.
Scrambled Eggs	-	-	-	-	-	Die, 60° Prod., R.T. 1 min. dwell	-
Chili Con Carne	10-20% H_2O Spray	-	R.T. ½-1½ Hr.	Combine Beef, Beans and Seasoning Mix	R.T. ½ Hr.	R.T.	45°C 28" Vac. 12 Hrs.
Chicken	10% G Spray	-	60°C 1 Hr.	-	-	60°C	-

Notes: *Depending on component; applied separately.

GA = Gum Arabic; PG = Propylene Glycol.

B. PRELIMINARY EQUIPMENT SELECTION

Equipment has been considered in some detail for the key operations of addition of anti-fragmentation agent and compression of food to form bars. This is discussed in the following paragraphs. Most of the other equipment which is not further discussed is available from a number of food equipment manufacturers. They will be able to make specific recommendations once a firm process design basis has been established.

In planning the preliminary flow diagram of Figure VIII, a target capacity of 50 bars per minute has been assumed.

1. Addition of Anti-Fragmentation Agent

As shown in Table XXVII, all products except scrambled eggs require an additive. Addition by spraying is the preferred method for all products except raw beef, to which the desired moisture level is achieved by use of a humidity chamber. Controlled spraying or atomization of liquids can be accomplished using nozzles, either the hydraulic pressure, single fluid type or the two-fluid (pneumatic) type. The single fluid, pressure type is not well suited for the low volume requirements and the high viscosities of some of the liquid additives used in this project.

Of the various two-fluid or pneumatic atomizing nozzles, the positive feed type is preferred for this application. With this type of nozzle, the liquid supply is regulated by a feed pump or a constant pressure supply system. This keeps liquid flow and air flow independent, allowing separate control over atomization by air regulation. This independence is important because of variations in liquid flow requirements and liquid properties (especially viscosity) from food product to food product. Spray set-up number 14 of Spraying Systems, Inc., is considered suitable for the commercial scale production line. To complete the spray set-up, certain other equipment is needed:

a. An air compressor to deliver up to 10 cfm of oil-free air at up to 50 psig.

b. An air pressure regulator.

c. A liquid metering pump to deliver between 1 and 5 gph. (This capacity includes 50% overspray, two spray stations).

Uniformity of spray application should be achieved by the use of two spray stations and the product turnover accompanying the transfer between conveyors. In addition, some degree of desirable agitation can be obtained from the fluidizing action of the atomizing air if the distance between product and nozzle is adjusted for this purpose.

2. Compression and Bar Formation From Prepared Food

The important items to be considered in the selection of a press for bar formation are listed in Table XXVIII. Also included are pertinent existing contract specifications. Experimental results and operating conventions have been included.

The data listed for the commercial equipment have been developed from discussion with equipment manufacturers and from their literature.

The Colton Rotary Tableting Press, Number 270, appears to be the best choice for an efficient commercial production unit for bar fabrication. According to a representative of Colton, the production of 50 food bars per minute would require certain modifications of the press to allow for the pressure build-up, dwell, and feed flow characteristics in bar production. The press has a rated capacity of 860 tablets per minute from powders of good flowability. The desirable slow build-up of pressure and dwell time needed for compression of dehydrated food bars is expected to be achieved by slow operation of this high capacity press.

During the experimental development work, this time was of necessity on the order of 10 seconds or more, using a hand operated Carver hydraulic press. In the Colton #270, a build-up time of 12 seconds would be obtained at a production rate of 50 tablets per minute.

Key items of equipment expected to be needed for small scale commercial production are shown functionally in Figure VIII.

TABLE 11

FOOD BAR FABRICATION - DETAILED COMPARISON OF PRESSING EQUIPMENT, CONTRACT SPECIFICATIONS AND EXPERIMENTAL DATA

1 No.	2 Item	3 Contract Specification	4 Experimental Result or Convention	5 Colton Single Punch #350	6 Stokes G-4	7 Colton Rotary #270, 25 Stations	8 Stokes Rotary #230, 10 Stations	9 Hydraulic Presses
				(Commercial Tableting Presses Considered)				
1	Weight	½"	½" ± 1/16" Obtained by predetermined fill & specified pressure.	Obtained by punch travel adjustment.	Same as Column 5.	Same as Column 5.	As Column 5.	As Column 5, or by combination of fill & press - control.
2	Diameter	1.6"	1.6" ± 0.1"	Determined by die used. Adjustable by insertion of sleeves. Max. 3.25".	As Column 5, except max. 2.25"	As Column 5, except max. 2".	As Column 5, except max. 2½".	Determined by die used. Dies obtained to specifications.
3	Loose Fill Depth	-	0.9"-2.8"	Adjustable to 2 1/8" Standard max. Modification possible to 2.75" max.	Adjustable to 4" max.	Adjustable to 2 3/4" std. Modification to 3½" possible.	Adjustable to 4¾" max.	Presses w. sufficient stroke available to accommodate desired fill depth.
4	Compression Ratio	-	1.8-5.6	4.25 Standard max. Modification to 5.5 max.	Up to 8	Up to 5.5	Up to 8.5	See above.
5	Applied Pressure	1000 psig	1100 psig	Up to 40,000 psi available	Up to 18,000 psi available	Up to 20,000 psi available	Up to 15,000 psi available	A 50 ton press will exert 1000 psi per bar if 50 bars are pressed per batch
6	Pressure Control	-	± 1000 tolerance	Not controlled directly. Actual exerted pressure controlled by fill.	As Column 5	As Column 5	As Column 5	Direct control possible except non-uniform from bar to bar in a given batch.
7	Time of Pressure Build-Up	-	10 seconds	Depends on speed of operation. At 50 bars min., ½ sec.	As Column 5, At 25 bars min, 1 sec.	As Column 5. At 50 bars/min, 12 sec.	As Column 5, At 50 bars/min, 5 sec.	May be controlled from 2 sec. up. No fixed relationship between this time & speed of operation.
8	Dwell Time at Pressure	-	5 seconds	Essentially none.	As Column 5.	At 50 bars/min, 2 RPM about 1.5 sec. Modification to 3 sec. possible.	At 50 bars/min, 5 RPM, about 0.6 sec. Modification possible.	No limitations. (Cont'd)
9	Heat Application	-	Preheated mold & Heating Platens for some products	Convenient only at product feed hopper.	As Column 5.	As Column 5.	As Column 5.	Heating can be provided at prod. hopper, on upper & lower platens, & on dies, if desired.
10	Speed of Operation	50/min.	1/min.	Up to 51/min.	Up to 36/min.	Up to 860/min.	65 or 91 bars/min. Modification possible.	Desired 50/min. feasible.
11	Filling Procedure		Pouring or indiv. piece placement, accord. to prod.	Gravity flow hopper. Indiv. placement not feasible.	As Column 5	Gravity flow hopper w. induced die feed. Indiv. placement possible by hand.	Gravity flow hopper w. induced feed. Indiv. placement by hand questionable because of speed.	Gravimetric flow hopper, hand fill, or indiv. piece placement by hand.
12	Uniformity of Fill	-	Pour volume or piece count.	Volumetric control.	As Column 5.	Volumetric control & piece counting.	Volumetric control only.	Volumetric or weight control, also piece counting.
13	Removal of Bar From Mold	-	By hand or hydraulic pressing.	Automatic machine expulsion.	As Column 5.	As Column 5.	As Column 5.	By hydraulic or mechanical pressing.
14	Auxiliary Equipment	-	-	None	None	None	None	Two extra sets of dies, demolder, filling station
15	Labor Required	-	-	One operator half time on standard prod. Operation on hand-placed items not feasible.	As Column 5	One operator ½ time on standard prod. Two full time operators for hand-placed items.	Column 7.	Three full time operators
16	Approximate Purchase Cost of Machine & Aux.	-	-	-	$11,000	$22,000	-	$4,000

FIGURE I

HUMIDITY - MOISTURE EQUILIBRIUM

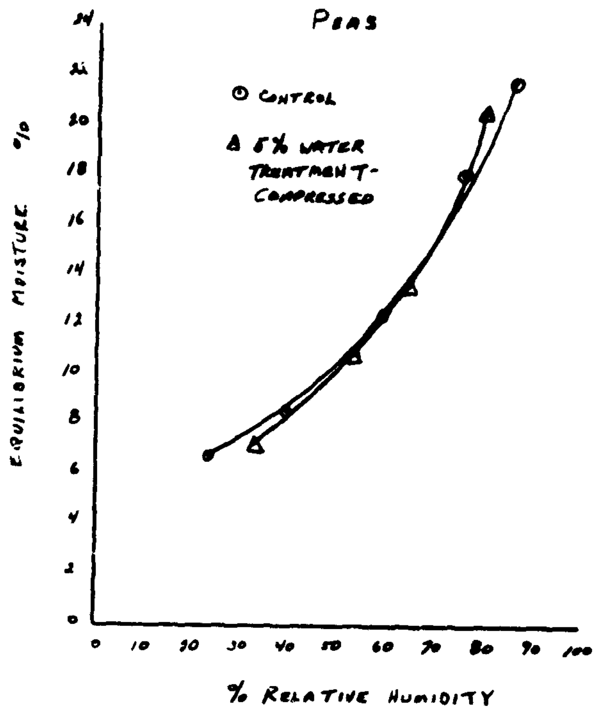


FIGURE II

HUMIDITY - MOISTURE EQUILIBRIUM

SHRIMP

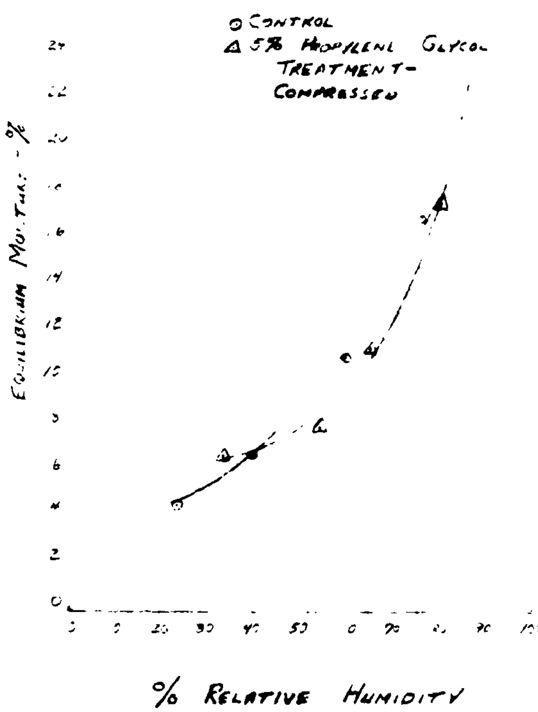


FIGURE IV

HUMIDITY- MOISTURE EQUILIBRIUM

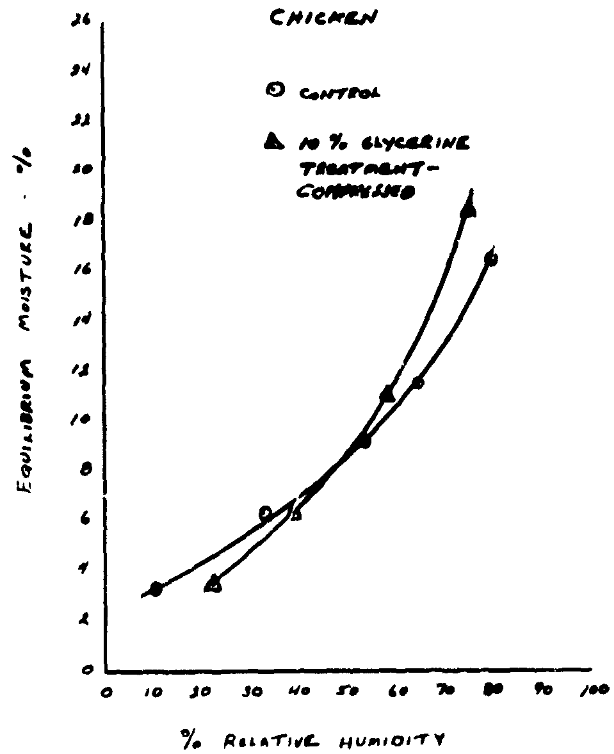


FIGURE III

HUMIDITY- MOISTURE EQUILIBRIUM

RICE

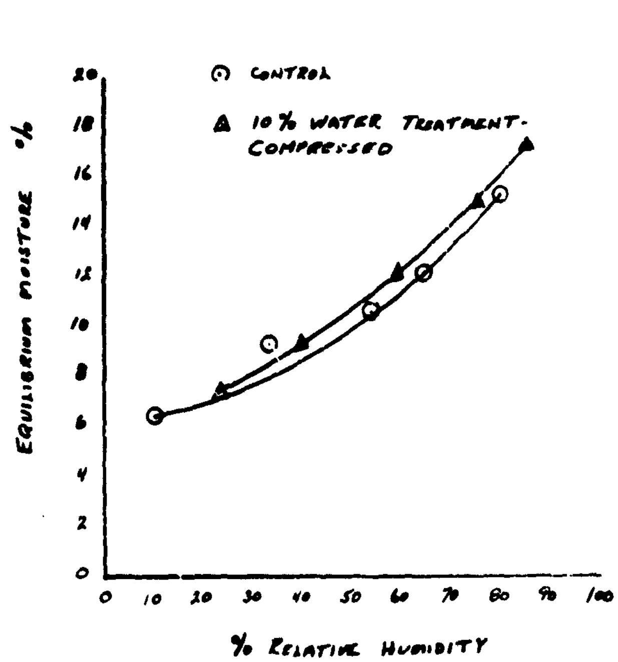


FIGURE V

HUMIDITY-MOISTURE EQUILIBRIUM

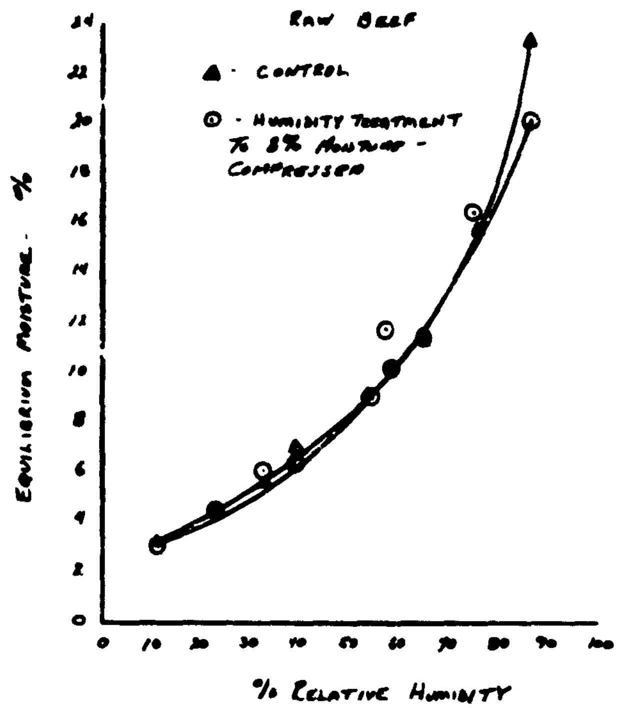


FIGURE VI

HUMIDITY - MOISTURE EQUILIBRIUM

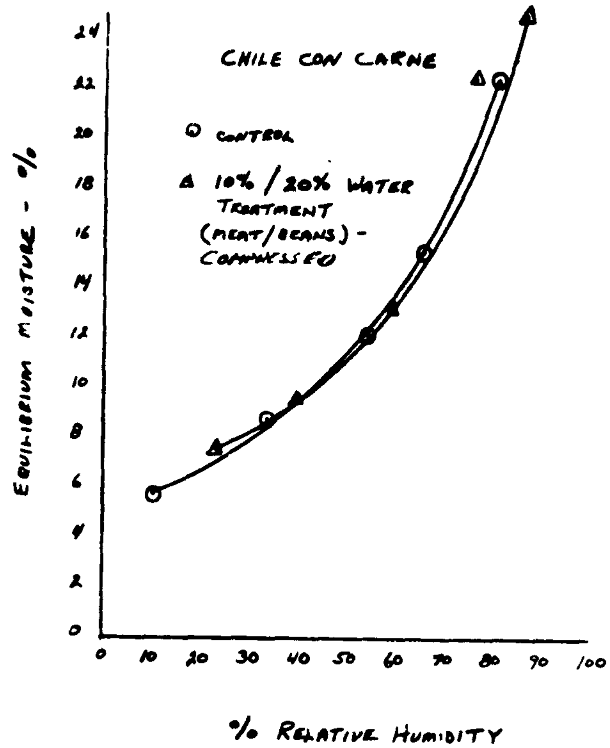
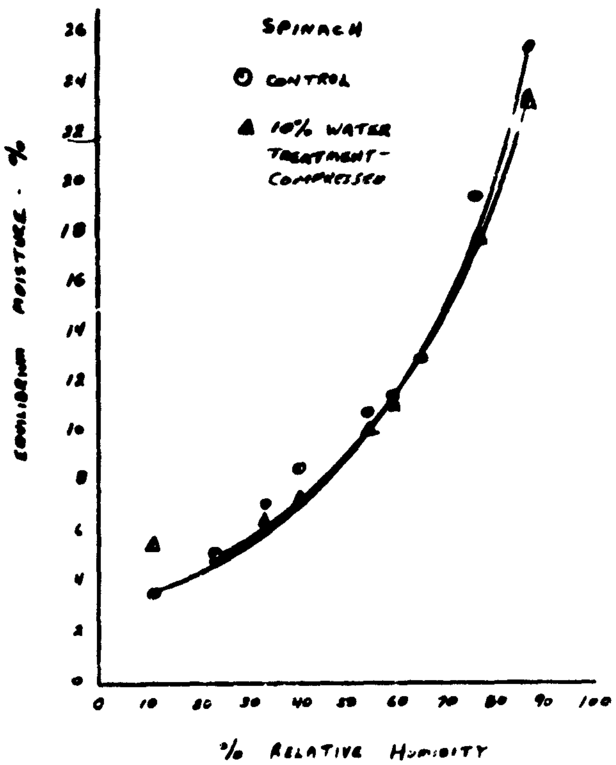
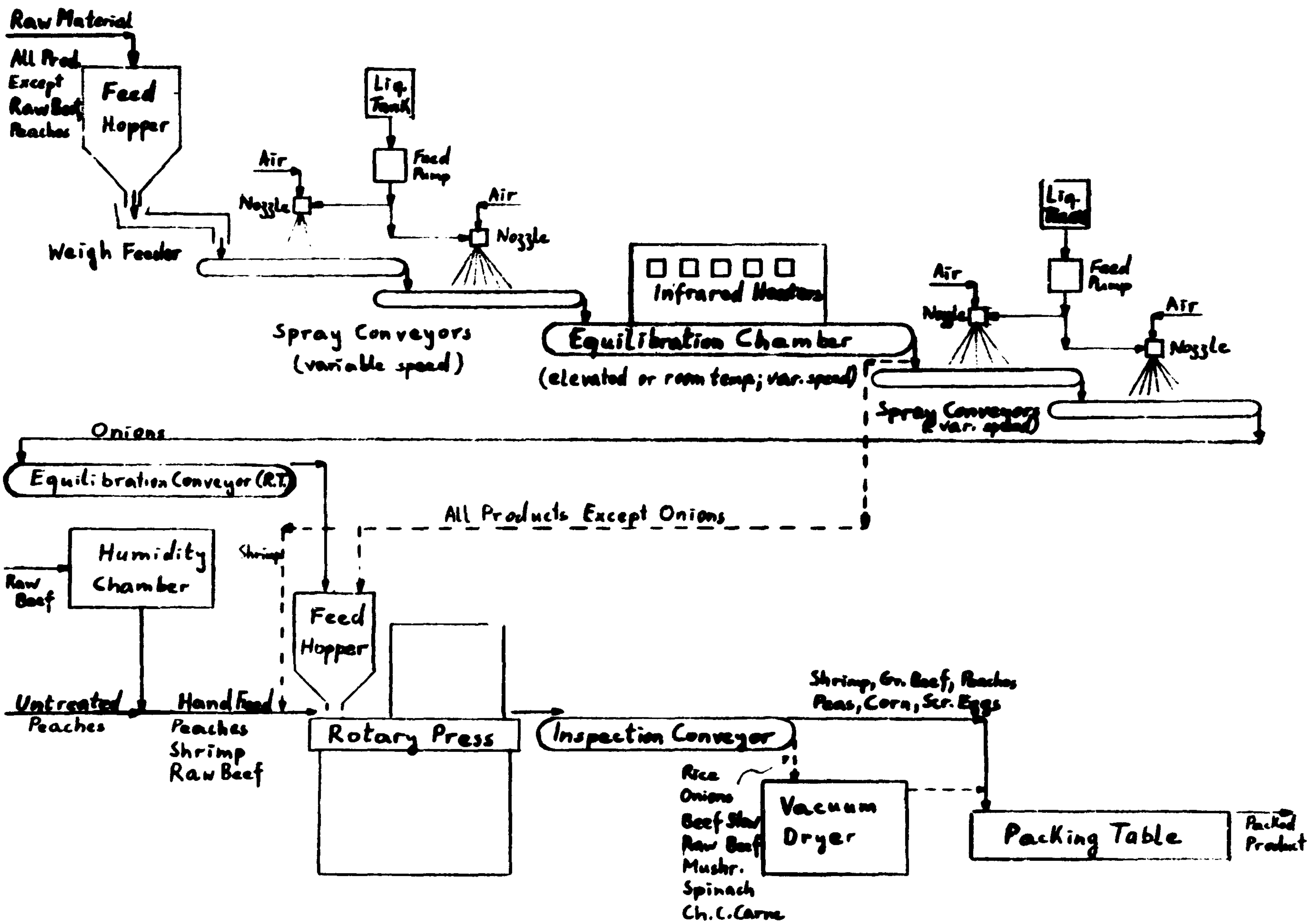


FIGURE VII

HUMIDITY-MOISTURE EQUILIBRIUM



... compressed food bar fabrication



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13. ABSTRACT

Methods have been developed whereby a broad range of dehydrated foods can be compressed at 1000 p.s.i. into dense, cohesive bars which rehydrate readily with little fragmentation to original characteristics. Examination included 15 food types. Measurement of fragmentation is described. Storage stability is reported. A progress flow chart is included.

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Fragmentation	8		9		3	
Control	8					
Dehydrated foods	1				1	
Freeze-dried foods	1				1	
Compressed foods	1		9			
Food bars	1		9		2	
Spraying	10					
Water	10					
Glycerin	10					
Propylene glycol	10					
Measurement			8			
Storage stability			9			
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Military rations					4	

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